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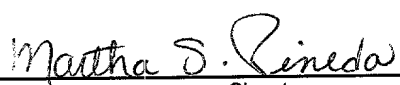
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March 31, 2000

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03/31/00

BOX PATENT APPLICATION

Assistant Commissioner for Patents
Washington, DC 20231

RE: *U.S. Patent Application Entitled: PREPARATION OF METADATA FOR SPLICING OF ENCODED MPEG VIDEO AND AUDIO - John Forecast, Daniel Gardere, Peter Bixby, Sorin Faibish, Wayne W. Duso (EMCR:054)*

Sir:

Transmitted herewith for filing are:

- (1) 76-page patent specification with 38 claims and an abstract (also Figures 1-52 on 40 sheets);
- (2) Signed Declaration; and
- (3) Assignment and Assignment Cover Sheet.
- (4) Preliminary Amendment

FILING FEE CALCULATION

FOR		Small Entity	Large Entity
Total Claims	38 - 20 = 18	x \$9 = \$	or x \$18 = \$ 324.00
Independent Claims	3 - 3 = 0	x \$39 = \$	or x \$78 = \$
Multiple Dependent Claim(s)		+ \$130 = \$	or + \$260 = \$
Basic Fee:		+ \$345 = \$	or + \$690 = \$ 690.00
Assignment Recording Fee: (\$40 per assignee)		+ = \$	+ \$40 = \$ 40.00
TOTAL FILING FEES		\$ 0.00	\$ 1,054.00

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Assistant Commissioner for Patents

March 31, 2000

Page 2

The Assistant Commissioner is authorized to deduct the above calculated filing fee from EMC Corporation's Deposit Account No. 05-0889/EMC-99-176. Should any additional fees under 37 C.F.R. §§ 1.16 to 1.21 be required for any reason in connection with this application, or should an overpayment be included herein, the Assistant Commissioner is authorized to deduct or credit said fees from or to EMC Corporation's Deposit Account No. 05-0889/EMC-99-176.

Pursuant to 37 C.F.R. § 1.10 the Applicant requests the Patent and Trademark Office to accept this application and accord a serial number and filing date as of the date this application is deposited with the U.S. Postal Service for Express Mail.

Please date stamp and return the enclosed postcard to evidence receipt of these materials.

Please forward any reply to this communication directly to our Houston office for docketing purposes. The mailing address is P.O. Box 4433, Houston, Texas, 77210-4433; the physical address for courier packages is 750 Bering Drive, Houston, Texas, 77057, and the Houston fax number is 713.787.1440.

Respectfully submitted,



Richard C. Auchterlonie

Reg. No. 30,607

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Martha S. Rineda
Signature

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:
John Forecast, et al.

Serial No.: Unknown

Filed:

For: PREPARATION OF METADATA FOR
SPLICING OF ENCODED MPEG VIDEO
AND AUDIO

Group Art Unit: Unknown

Examiner: Unknown

Atty. Dkt. No.: EMCR:054/AUC

PRELIMINARY AMENDMENT

Assistant Commissioner for Patents
Washington, DC 20231

Sir:

Please amend the above-identified application as follows:

In the Claims:

In Claim 19, line 1, please change "20" to --18--.

PATENT
EMCR:054
EMC-99-176

APPLICATION FOR UNITED STATES LETTERS PATENT

for

Preparation of Metadata for Splicing of Encoded MPEG Video and Audio

by

John Forecast
Daniel Gardere
Peter Bixby
Sorin Faibish
Wayne W. Duso

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Martha S. Rineda

Signature

RELATED APPLICATIONS

This application is a division of Provisional Application Ser. No. 60/174,360 filed Jan. 4, 2000, incorporated herein by reference.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates to processing of compressed audio/visual data, and more particularly to splicing of streams of audio/visual data.

2. Background Art.

It has become common practice to compress audio/visual data in order to reduce the capacity and bandwidth requirements for storage and transmission. One of the most popular audio/video compression techniques is MPEG. MPEG is an acronym for the Moving Picture Experts Group, which was set up by the International Standards Organization (ISO) to work on compression. MPEG provides a number of different variations (MPEG-1, MPEG-2, etc.) to suit different bandwidth and quality constraints. MPEG-2, for example, is especially suited to the storage and transmission of broadcast quality television programs.

For the video data, MPEG provides a high degree of compression (up to 200:1) by encoding 8 x 8 blocks of pixels into a set of discrete cosine transform (DCT) coefficients, quantizing and encoding the coefficients, and using motion compensation techniques to encode most video frames as predictions from or between other frames. In particular, the encoded MPEG video stream is comprised of a series of groups of pictures (GOPs), and each GOP begins with an independently encoded (intra) I frame and may

1 include one or more following P-frames and B-frames. Each I frame can be decoded
2 without information from any preceding and/or following frame. Decoding of a P frame
3 requires information from a preceding frame in the GOP. Decoding of a B frame requires
4 information from a preceding and following frame in the GOP. To minimize decoder
5 buffer requirements, each B frame is transmitted in reverse of its presentation order, so
6 that all the information of the other frames required for decoding the B frame will arrive
7 at the decoder before the B frame.

8 In addition to the motion compensation techniques for video compression, the
9 MPEG standard provides a generic framework for combining one or more elementary
10 streams of digital video and audio, as well as system data, into single or multiple program
11 transport streams (TS) which are suitable for storage or transmission. The system data
12 includes information about synchronization, random access, management of buffers to
13 prevent overflow and underflow, and time stamps for video frames and audio packetized
14 elementary stream packets. The standard specifies the organization of the elementary
15 streams and the transport streams, and imposes constraints to enable synchronized
16 decoding from the audio and video decoding buffers under various conditions.

17 The MPEG 2 standard is documented in ISO/IEC International Standard (IS)
18 13818-1, "Information Technology-Generic Coding of Moving Pictures and Associated
19 Audio Information: Systems," ISO/IEC IS 13818-2, "Information Technology-Generic
20 Coding of Moving Pictures and Associated Information: Video," and ISO/IEC IS 13818-
21 3, "Information Technology-Generic Coding of Moving Pictures and Associated Audio
22 Information: Audio," incorporated herein by reference. A concise introduction to MPEG

1 is given in "A guide to MPEG Fundamentals and Protocol Analysis (Including DVB and
2 ATSC)," Tektronix Inc., 1997, incorporated herein by reference.

3 Splicing of audio/visual programs is a common operation performed, for example,
4 whenever one encoded television program is switched to another. Splicing may be done
5 for commercial insertion, studio routing, camera switching, and program editing. The
6 splicing of MPEG encoded audio/visual streams, however, is considerably more difficult
7 than splicing of the uncompressed audio and video. The P and B frames cannot be
8 decoded without a preceding I frame, so that cutting into a stream after an I frame renders
9 the P and B frames meaningless. The P and B frames are considerably smaller than the I
10 frames, so that the frame boundaries are not evenly spaced and must be dynamically
11 synchronized between the two streams at the time of the splice. Moreover, because a
12 video decoder buffer is required to compensate for the uneven spacing of the frame
13 boundaries in the encoded streams, splicing may cause underflow or overflow of the
14 video decoder buffer.

15 The problems of splicing MPEG encoded audio/visual streams are addressed to
16 some extent in Appendix K, entitled "Splicing Transport Streams," to the MPEG-2
17 standard ISO/IEC 13818-1 1996. Appendix K recognizes that a splice can be "seamless"
18 when it does not result in a decoding discontinuity, or a splice can be "non-seamless"
19 when it results in a decoding discontinuity. In either case, however, it is possible that the
20 spliced stream will cause buffer overflow.

21 The Society of Motion Picture and Television Engineers (SMPTE) apparently
22 thought that the ISO MPEG-2 standard was inadequate with respect to splicing. They
23 promulgated their own SMPTE Standard 312M, entitled "Splice Points for MPEG-2

1 Transport Streams," incorporated herein by reference. The SMPTE standard defines
2 constraints on the encoding of and syntax for MPEG-2 transport streams such that they
3 may be spliced without modifying the packetized elementary stream (PES) packet
4 payload. The SMPTE standard includes some constraints applicable to both seamless
5 and non-seamless splicing, and other constraints that are applicable only to seamless
6 splicing. For example, for seamless and non-seamless splicing, a splice occurs from an
7 Out Point on a first stream to an In Point on a second stream. The Out Point is
8 immediately after an I frame or P frame (in presentation order). The In Point is just
9 before a sequence header and I frame in a "closed" GOP (i.e., no prediction is allowed
10 back before the In Point).

11 As further discussed in Norm Hurst and Katie Cornog, "MPEG Splicing: A New
12 Standard for Television - SMPTE 312M," SMPTE Journal, Nov. 1998, there are two
13 buffering constraints for seamless splicing. The startup delay at the In Point must be a
14 particular value, and the ending delay at the Out Point must be one frame less than that.
15 Also, the old stream must be constructed so that the video decoder buffer (VBV buffer)
16 would not overflow if the bit rate were suddenly increased to a maximum splice rate for a
17 period of a splice decoding delay before each Out Point.

18

19 SUMMARY OF THE INVENTION

20 In accordance with a first aspect, the invention provides a method of
21 preparing metadata for splicing of a transport stream. The transport stream includes
22 video access units encoding video presentation units representing video frames. The
23 video access units of the transport stream encode the video presentation units using a data

1 compression technique and contain a variable amount of compressed video data. The
2 method includes a file server ingesting the transport stream, and storing the transport
3 stream in a file in data storage. Concurrently with storing the transport stream in the file
4 in data storage, the file server computes metadata for splicing of the transport stream, and
5 stores the metadata for splicing in the file.

6 In accordance with another aspect, the invention provides a data storage device
7 containing a file of data of a transport stream including video access units encoding video
8 presentation units representing video frames. The video access units of the transport
9 stream encode the video presentation units using a data compression technique and
10 contain a variable amount of compressed video data. The file also contains an index to
11 groups of pictures (GOPs) in the transport stream. The index to the groups of pictures
12 includes pointers to transport stream file data of respective ones of the GOPs. The file
13 further contains attributes of the GOPs computed from the data of the transport stream.
14 The attributes of the GOPs are also indexed by the index to the groups of pictures.

15 16 BRIEF DESCRIPTION OF THE DRAWINGS

17 Other objects and advantages of the invention will become apparent upon reading
18 the following detailed description with reference to the accompanying drawings, in
19 which:

20 FIG. 1 is a block diagram of a video file server;

21 FIG. 2 is a perspective view showing the use of a set-top decoder box;

22 FIG. 3 is a block diagram showing a switch for splicing broadcast audio/visual
23 streams;

1 FIG. 4 is a block diagram of an MPEG decoder;

2 FIG. 5 is a diagram of the format of an MPEG transport packet stream;

3 FIG. 6 is a diagram of the format of an MPEG PES packet;

4 FIG. 7 is a diagram showing audio and video content in two MPEG transport
5 streams to be spliced;

6 FIG. 8 is a diagram showing aligned elementary video and audio streams resulting
7 from the splicing of the two MPEG transport streams in FIG. 7;

8 FIG. 9 is a diagram showing that audio access units are not aligned on audio PES
9 packet boundaries;

10 FIG. 10 is a logic table showing eight cases for the selection of audio presentation
11 units to be included in the splicing of two MPEG transport streams;

12 FIG. 11A is a diagram showing content of video and audio presentation unit
13 streams for the two MPEG transport streams for a first case in the logic table of FIG. 10;

14 FIG. 11B is a diagram showing the content of video and audio presentation unit
15 streams resulting from a first possible splicing of the two MPEG transport streams shown
16 in FIG. 11A;

17 FIG. 11C is a diagram showing the content of video and audio presentation unit
18 streams resulting from a second possible splicing of the two MPEG transport streams
19 shown in FIG. 11A;

20 FIG. 12A is a diagram showing content of video and audio presentation unit
21 streams for the two MPEG transport streams for a second case in the logic table of FIG.
22 10;

1 FIG. 12B is a diagram showing the content of video and audio presentation unit
2 streams resulting from splicing of the two MPEG transport streams shown in FIG. 12A;

3 FIG. 13A is a diagram showing content of video and audio presentation unit
4 streams for the two MPEG transport streams for a third case in the logic table of FIG. 10;

5 FIG. 13B is a diagram showing the content of video and audio presentation unit
6 streams resulting from splicing of the two MPEG transport streams shown in FIG. 13A;

7 FIG. 14A is a diagram showing content of video and audio presentation unit
8 streams for the two MPEG transport streams for a fourth case in the logic table of FIG.
9 10;

10 FIG. 14B is a diagram showing the content of video and audio presentation unit
11 streams resulting from splicing of the two MPEG transport streams shown in FIG. 14A;

12 FIG. 15A is a diagram showing content of video and audio presentation unit
13 streams for the two MPEG transport streams for a fifth case in the logic table of FIG. 10;

14 FIG. 15B is a diagram showing the content of video and audio presentation unit
15 streams resulting from splicing of the two MPEG transport streams shown in FIG. 15A;

16 FIG. 16A is a diagram showing content of video and audio presentation unit
17 streams for the two MPEG transport streams for a sixth case in the logic table of FIG. 10;

18 FIG. 16B is a diagram showing the content of video and audio presentation unit
19 streams resulting from splicing of the two MPEG transport streams shown in FIG. 16A;

20 FIG. 17A is a diagram showing content of video and audio presentation unit
21 streams for the two MPEG transport streams for a seventh case in the logic table of FIG.
22 10;

1 FIG. 17B is a diagram showing the content of video and audio presentation unit
2 streams resulting from a first possible splicing of the two MPEG transport streams shown
3 in FIG. 17A;

4 FIG. 17C is a diagram showing the content of video and audio presentation unit
5 streams resulting from a second possible splicing of the two MPEG transport streams
6 shown in FIG. 17A;

7 FIG. 18A is a diagram showing content of video and audio presentation unit
8 streams for the two MPEG transport streams for an eighth case in the logic table of FIG.
9 10;

10 FIG. 18B is a diagram showing the content of video and audio presentation unit
11 streams resulting from splicing of the two MPEG transport streams shown in FIG. 18A;

12 FIG. 19 is a flow chart of a procedure for splicing MPEG clips;

13 FIG. 20A is a graph of video buffer level versus time for decoding the end of a
14 first MPEG clip;

15 FIG. 20B is a graph of video buffer level versus time for decoding the beginning
16 of a second MPEG clip;

17 FIG. 21 is a graph of video buffer level versus time for decoding of a seamless
18 splicing of the first MPEG clip to the second MPEG clip;

19 FIG. 22 is a flow chart of a basic procedure for seamless splicing of video
20 streams;

21 FIG. 23 is a first portion of a flow chart of a procedure for splicing video streams;

22 FIG. 24 is a second portion of the flow chart begun in FIG. 23;

23 FIG. 25 is a first portion of a flow chart of a procedure for splicing audio streams;

1 FIG. 26 is a second portion of the flow chart begun in FIG. 25;

2 FIG. 27 is a logic table showing how the first and second clips for the cases of
3 FIGS. 11A to 18A should be spliced when the second clip has a high or low mean audio
4 buffer level close to overflowing or underflowing respectively;

5 FIG. 28 shows how the first and second clips for the case of FIG. 11A should be
6 spliced when the second clip has a high mean audio buffer level;

7 FIG. 29 shows how the first and second clips for the case of FIG. 12A should be
8 spliced when the second clip has a low mean audio buffer level;

9 FIG. 30 shows how the first and second clips for the case of FIG. 13A should be
10 spliced when the second clip has a low mean audio buffer level;

11 FIG. 31 shows how the first and second clips for the case of FIG. 14A should be
12 spliced when the second clip has a high mean audio buffer level;

13 FIG. 32 shows how the first and second clips for the case of FIG. 15A should be
14 spliced when the second clip has a low mean audio buffer level;

15 FIG. 33 shows how the first and second clips for the case of FIG. 16A should be
16 spliced when the second clip has a high mean audio buffer level;

17 FIG. 34 shows how the first and second clips for the case of FIG. 17A should be
18 spliced when the second clip has a low mean audio buffer level;

19 FIG. 35 shows how the first and second clips for the case of FIG. 18A should be
20 spliced when the second clip has a high mean audio buffer level;

21 FIG. 36 is a schematic diagram of a digital filter for estimating the average audio
22 buffer level and standard deviation of the audio buffer level from presentation time

1 stamps (PTS) and extrapolated program clock reference (PCR) time stamps for an audio
2 elementary stream;

3 FIG. 37 is a schematic diagram of circuitry for computing an expected maximum
4 and an expected minimum audio buffer level from the estimated average audio buffer
5 level and standard deviation of the average audio buffer level from the digital filter
6 circuitry in FIG. 36;

7 FIG. 38 is a flow chart of a procedure for computing an offset for the video
8 decode time stamps (DTS) of the second clip for splicing the second clip onto the first
9 clip;

10 FIG. 39 is a flow chart of a procedure for computing an offset for the audio
11 presentation time stamps (PTS) of the second clip for splicing the second clip onto the
12 first clip;

13 FIG. 40 is a flow chart of a procedure for computing an offset for the program
14 clock reference (PCR) time stamps of the second clip for splicing the second clip to the
15 first clip;

16 FIG. 41 is a flow chart of a procedure for re-stamping a second clip for splicing of
17 the second clip to the first clip;

18 FIG. 42 is a diagram of macroblocks in a video frame;

19 FIG. 43 is a diagram showing non-obsolete audio packets in a first TS stream
20 following the end of video at an Out Point and null packets and obsolete audio packets in
21 a second TS stream following the beginning of video at an In Point;

22 FIG. 44 is a flow chart of a re-formatting procedure that replaces the null packets
23 and obsolete audio packets in FIG. 43 with the non-obsolete audio packets in FIG. 43;

1 FIG. 45 is a diagram showing MPEG Transport Stream (TS) metadata
2 computation and storage of the metadata in the header of an MPEG TS data file;

3 FIG. 46 is a block diagram of the preferred format of a GOP index introduced in
4 FIG. 45;

5 FIG. 47 is a flow chart showing decimation of the GOP index;

6 FIG. 48 is a flow chart showing metadata computations for a next GOP in an
7 ingested TS;

8 FIG. 49 is a block diagram of various blocks in the stream server computer of the
9 video file server of FIG. 1 for computing MPEG metadata during ingestion of an MPEG
10 TS, and for performing real-time MPEG processing such as seamless splicing in real-time
11 during real-time transmission of a spliced MPEG TS;

12 FIG. 50 is a diagram showing flow of control during a metered file transfer using
13 the video server of FIG. 1;

14 FIG. 51 is a block diagram of play lists in the video file server of FIG. 1, showing
15 that a stream server play list is maintained as a window into a control station play list;
16 and

17 FIG. 52 is a flow chart showing the use of seamless splicing for repair of a
18 temporarily corrupted TS.

19 While the invention is susceptible to various modifications and alternative forms,
20 specific embodiments thereof have been shown in the drawings and will be described in
21 detail. It should be understood, however, that it is not intended to limit the form of the
22 invention to the particular forms shown, but on the contrary, the intention is to cover all

1 modifications, equivalents, and alternatives falling within the scope of the invention as
2 defined by the appended claims.

4 DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

5 Turning now to FIG. 1 of the drawings, there is shown a video file server
6 generally designated 20 which may use the present invention. The video file server 20
7 includes an array of stream servers 21, at least one control server 28, 29, a cached disk
8 array storage subsystem 23, and an optional tape silo 24. The video file server 20 is a
9 high performance, high capacity, and high-availability network-attached data server. It
10 provides the ability for multiple file systems to exist concurrently over multiple
11 communication stacks, with shared data access. It also allows multiple physical file
12 systems to co-exist, each optimized to the needs of a particular data service.

13 The video file server 20 is managed as a dedicated network appliance, integrated
14 with popular network operating systems in a way, which, other than its superior
15 performance, is transparent to the end user. It provides specialized support for real-time
16 data streams used in live, as well as store-and-forward, audio-visual applications.
17 Therefore, the video file server 20 is suitable for a wide variety of applications such as
18 image repositories, video on demand, and networked video applications, in addition to
19 high-end file server applications such as the Network File System (NFS, version 2 and
20 version 3) (and/or other access protocols), network or on-line backup, fast download, etc.

21 The clustering of the stream servers 21 as a front end to the cached disk array 23
22 provides parallelism and scalability. The clustering of random-access memory in the
23 stream servers 21 provides a large capacity cache memory for video applications.

1 Each of the stream servers 21 is a high-end commodity computer, providing the
2 highest performance appropriate for a stream server at the lowest cost. The stream
3 servers 21 are mounted in a standard 19" wide rack. Each of the stream servers 21, for
4 example, includes an Intel processor connected to an EISA or PCI bus and at least 64
5 MB of random-access memory. The number of the stream servers 21, their processor
6 class (i486, Pentium, etc.) and the amount of random-access memory in each of the
7 stream servers, are selected for desired performance and capacity characteristics, such as
8 the number of concurrent users to be serviced, the number of independent multi-media
9 programs to be accessed concurrently, and the desired latency of access to the multi-
10 media programs.

11 Each of the stream servers 21 contains one or more high-performance FWD (fast,
12 wide, differential) SCSI connections to the back-end storage array. Each of the stream
13 servers 21 may also contain one or more SCSI connections to the optional tape silo 24.
14 Each of the stream servers 21 also contains one or more outbound network attachments
15 configured on the stream server's EISA or PCI bus. The outbound network attachments,
16 for example, are Ethernet, FDDI, ATM, DS1, DS3, or channelized T3 attachments to data
17 links to a network 25. Each of the stream servers 21 also includes an additional Ethernet
18 connection to a dual redundant internal Ethernet link 26 for coordination of the stream
19 servers with each other and with one or more controller servers 28, 29.

20 The controller servers 28, 29 are dual redundant computers 28, 29, each of which
21 is similar to each of the stream servers 21. Each of the dual redundant controller servers
22 28, 29 has a network attachment to a bidirectional link 30 in the network 25, through
23 which each of the controller servers 28, 29 can conduct service protocols. The service

1 protocols include one or more standard management and control protocols such as the
2 Simple Network Management Protocol (SNMP), and at least one Continuous Media File
3 Access Protocol supporting real-time multi-media data transmission from the stream
4 servers 21 to the network 25.

5 Each of the dual redundant controller servers 28, 29 has an Ethernet connection to
6 the local Ethernet link 26. Each of the controller servers 28, 29 also has a connection to a
7 serial link 31 to a media server display and keyboard 32. The controller servers 28, 29
8 run a conventional operating system (such as Windows NT or UNIX) to provide a hot-
9 failover redundant configuration. An active one of the dual redundant controller servers
10 28, 29 functions as a media server controller for the video file server 20. The active one
11 of the controller servers 28, 29 also allows management and control of the server
12 resources from the network using standard protocols, such as the Simple Network
13 Management Protocol (SNMP). The active one of the controller servers 28, 29 may also
14 provide lock management if lock management is not provided by the cached disk array
15 23.

16 For multi-media data transfer, the active one of the controller servers 28, 29
17 assigns one of the stream servers 21 to the network client 54 requesting multi-media
18 service. The network 25, for example, has conventional transmission components 53
19 such as routers or ATM switches that permit any one of the clients 54 to communicate
20 with any one of the stream servers 21. The active one of the controller servers 28, 29
21 could assign a stream server to a network client by a protocol sending to the client the
22 network address of the stream server assigned to send or receive data to or from the
23 client. Alternatively, the active one of the controller servers 28, 29 could communicate

1 with a router or switch in the transmission components 53 to establish a data link between
2 the client and the stream server assigned to the client.

3 The cached disk array 23 is configured for an open systems network environment.

4 The cached disk array 23 includes a large capacity semiconductor cache memory 41 and

5 SCSI adapters 45 providing one or more FWD SCSI links to each of the stream servers

6 21 and to each of the dual redundant controller servers 28, 29. The disk array 47 may

7 store data using mirroring or other RAID (redundant array of inexpensive disks)

8 techniques to recover from single disk failure. Although simple mirroring requires more

9 storage disks than the more complex RAID techniques, it has been found very useful for

10 increasing read access bandwidth by a factor of two by simultaneously accessing each of

11 two mirrored copies of a video data set. Preferably, the cached disk array 23 is a

12 Symmetrix 5500 (Trademark) cached disk array manufactured by EMC Corporation, 171

13 South Street, Hopkinton, Mass., 01748-9103.

14 The tape silo 24 includes an array of SCSI adapters 50 and an array of read/write

15 stations 51. Each of the read/write stations 51 is connected via a respective one of the

16 SCSI adapters 50 and a FWD SCSI link to a respective one of the stream servers 21 or

17 each of the redundant controller servers 28, 29. The read/write stations 51 are controlled

18 robotically in response to commands from the active one of the controller servers 28, 29

19 for tape transport functions, and preferably also for mounting and unmounting of tape

20 cartridges into the read/write stations from storage bins.

21 Further details regarding the structure and operation of the video file server 20 are

22 found in Wayne Duso and John Forecast, "System Having Client Sending Edit

23 Commands to Server During Transmission of Continuous Media from One Clip in Play

1 List for Editing the Play List," U.S. Patent 5,892,915, issued April 6, 1999, incorporated
2 herein by reference. For practicing the present invention, the tape library 52 or cached
3 disk array 47 stores video clips in a compressed format. Each clip, for example, is a
4 recorded MPEG transport stream, including a video elementary stream and one or more
5 audio elementary streams synchronized to the video elementary stream. By using the
6 splicing techniques as described below, it is possible for the video file server to make a
7 seamless transition to a second clip from an intermediate location in a first clip during
8 real-time audio/video data transmission from the video file server 20 to one of the clients
9 54. In this regard, for the purposes of interpreting the appended claims, "seamless
10 splicing" should be understood to mean a process that will produce a spliced transport
11 stream, the play-out of which is substantially free from any audio-visual artifact that the
12 human auditory and visual system can detect.

13 With reference to FIG. 2, there is shown another application for seamless splicing
14 of MPEG transport streams. In this application, a set-top decoder box 61 receives a
15 number of MPEG transport streams from a coaxial cable 62. Each of the MPEG
16 transport streams encodes audio and video information for a respective television
17 channel. A viewer (not shown) may operate a remote control 63 to select one of the
18 channels for viewing on a television 64. The decoder box 61 selects the MPEG transport
19 stream for the desired channel and decodes the transport stream to provide a conventional
20 audio/visual signal (such as an NTSC composite analog audio/video signal) to the
21 television set.

22 In the set-top application as shown in FIG. 2, a problem arises when the viewer
23 rapidly scans through the channels available from the decoder 61. If a simple

1 transport stream and the video frames and corresponding audio signals for another
2 transport stream, and re-encode the video frames and audio signals to produce the spliced
3 MPEG transport stream. However, the computational and storage resources needed for
4 decoding the MPEG transport streams and encoding the spliced video frames and audio
5 signals can be avoided using the seamless splicing procedure described below.

6 In the switch 70, a de-multiplexer 77 switches from a current MPEG transport
7 stream to a new MPEG transport stream. The MPEG transport stream selected by the
8 multiplexer 77 is received by an MPEG splicer 78, which performs seamless splicing as
9 described below. The MPEG splicer 78 includes a central processor unit (CPU) and
10 random access memory 80. The random access memory provides buffering of the MPEG
11 transport stream selected by the multiplexer 77 so that at the time of splicing, the splicer
12 78 will have in the memory 80 a portion of the current MPEG transport stream near the
13 splice point, and a beginning portion of the new MPEG transport stream. The splicer 78
14 outputs a spliced MPEG transport stream that can be transmitted to customers, for
15 example, from a broadcast antenna 81.

16 With reference to FIG. 4, there is shown a block diagram of an MPEG decoder.
17 The decoder includes a demultiplexer 90, which receives a transport stream (TS) of
18 packets. The demultiplexer extracts a stream of video packetized elementary stream (V-
19 PES) packets, and two streams of audio packetized elementary stream (A-PES) packets.
20 A video buffer 91 receives the stream of V-PES packets, a first audio buffer 92 receives
21 the first stream of A-PES packets, and a second audio buffer 93 receives the second
22 stream of A-PES packets. A video decoder 94 receives the V-PES packets from the
23 video buffer 91 and produces video presentation units (VPUs). Each VPU, for example,

1 includes digital data specifying the color and intensity of each pixel in a video frame. A
2 first audio decoder 95 receives A-PES packets from the first audio buffer 92 and
3 produces audio presentation units (APUs) for a first audio channel. An audio
4 presentation unit, for example, includes digital data specifying a series of audio samples
5 over an interval of time. A second audio decoder 96 receives A-PES packets from the
6 second audio buffer 93 and produces APUs for a second audio channel. The first and
7 second channels, for example, are right and left stereo audio channels.

8 For seamless splicing of MPEG transport streams, it is not necessary to decode
9 the video and audio elementary streams down to the presentation unit level, nor is it
10 necessary to simulate the video and audio buffers. Instead, the transport stream need only
11 be parsed down to the level of the packetized elementary streams and access units, and
12 the video and audio buffers need be considered only to the extent of avoiding buffer
13 overflow or underflow. As will be described below, buffer overflow or underflow can be
14 avoided by estimating buffer level based on program clock reference (PCR) and decode
15 time stamp (DTS) values. Seamless splicing can be done independently of the method of
16 audio encoding, although the estimation of buffer level can be made more precise by
17 taking into consideration certain encoded data statistics, which happen to be dependent
18 on the type of audio encoding. It is desired to provide a generic splicing method in which
19 no constraining assumptions are made about various encoding parameters such as frame
20 rate, audio bit rate, and audio sampling frequency. It is also desired to achieve splicing
21 directly on the transport streams with as little complexity as possible.

22 FIG. 5 is a diagram showing the syntax of the MPEG-2 Transport Stream. This
23 diagram is a relevant portion of Figure F.1 of Annex F of the MPEG-2 standards

document ISO/IEC 13818-1. The MPEG-2 Transport Stream is comprised of a series of 188 byte TS packets, each of which may include video, audio, or control information. Seamless splicing, as described below, may involve modification of the payload unit start indicator, the packet identifier (PID), the continuity counter field, the adaptation field length in the adaptation field, and the program counter (PCR) time stamp again provided in the adaptation field. If the data of a video PES packet or audio PES packet starts in the payload of a TS packet, then the payload unit start indicator bit is set to a one. Otherwise, if the TS packet contains the continuation of an already initiated audio or video PES packet, then the payload unit start indicator bit is set to zero. Very typically the payload unit start indicator will be changed by setting it to one at the first TS packet of the audio for the second stream in the spliced Transport Stream. The original continuity counter values of the second stream are modified so that the continuity counter values in the spliced TS have consecutive values. The adaptation field length in the adaptation fields of the last audio TS packet in the first stream and also the first audio TS packet in the second stream within the spliced TS will typically need to be modified during splicing in order to insert some stuffing bytes to generate full 188 byte sized valid transport packets. The original PCR values from the second stream are uniformly incremented in the spliced TS.

FIG. 6 is a diagram showing the syntax of an MPEG-2 PES packet. This diagram is a relevant portion of Figure F.2 of Annex F of the MPEG-2 standards document ISO/IEC 13818-1. The MPEG-2 PES packet may include video, audio, or control information. Seamless splicing, as described below, may involve modification of the PES packet length, and the data alignment indicator and presentation time stamp (PTS)

1 and decode time stamp (DTS) in the PES header. During splicing, the PES packet length
2 typically has to be modified for the audio, in two places. The first is the last audio PES
3 packet of the first stream, where the information about the size often has to be changed.
4 The size should refer to the bytes preserved in these two audio PES packets after editing
5 for splicing is made. The data alignment indicator may also change in the first audio PES
6 packet of the second stream due to deletion of some obsolete audio access units. The
7 original PTS and DTS values from the second stream are uniformly incremented in the
8 spliced TS.

9 In general, splicing of MPEG-2 Transport Streams involves selecting an end point
10 in a first MPEG-2 TS stream, selecting a beginning point in a second MPEG-2 TS
11 stream, combining the content of the first TS stream prior in presentation order to the end
12 point with the content of the second TS stream subsequent in presentation order to the
13 beginning point. Unfortunately, the TS streams are formatted so that the presentation
14 order is often different from the order in which the content appears in the TS streams. In
15 particular, transport packets including audio information are delayed with respect to
16 corresponding transport packets of video information. Moreover, as noted above, the B
17 frames appear in the TS streams in reverse of their presentation order with respect to the
18 reference frames that immediately follow the B frames. As shown in FIG. 7, for
19 example, the first Transport Stream 101 and the second Transport Stream 102 are
20 subdivided by a dashed cut line 103 which indicates which of the audio packets (A1) and
21 video packets (V1) in the first stream appear in presentation order before the end point,
22 and which of the audio packets (A2) and video packets (V2) in the second stream 102
23 appear in presentation order after the beginning point. Due to this problem, the transport

streams are parsed prior to splicing to determine the relative presentation time of the video and audio information around the desired beginning and end points. In addition, splicing is more difficult than just removing certain Transport Stream packets from the first and second Transport Streams and concatenating the two streams. In general, the audio data to keep and the audio data to discard will not be segregated into contiguous blocks in the Transport Streams. Typically the splicing operation will involve re-formatting of the audio data in the spliced Transport Stream, as discussed below with reference to FIG. 43.

As shown in FIG. 8, the portion of the first Transport Stream prior to the end point has been parsed into a video PES stream 111 and an audio PES stream 112, and the portion of the second Transport Stream after the beginning point has been parsed into a video PES stream 113 and an aligned audio PES stream 114. The two video PES streams 111, 113 have been jointed together at a dashed cut line 115, and the two audio PES streams have been also joined at the dashed cut line 115. The natural cut point for the audio stream, however, is not between video PES boundaries, and instead it is between audio access units (AAU) which are decoded to produce corresponding audio presentation units (APU). Therefore, there may be a slight gap or overlap at the cut line 115 between the AAUs from the first Transport Stream and the AAUs from the second Transport Stream. The gap or the overlap is removed during a reformatting operation in which the spliced Transport Stream is produced from the parsed video PES stream and the parsed audio PES stream. Typically the reformatting operation will slightly shift the alignment of the audio presentation units from the second Transport Stream with respect to their corresponding video presentation units.

1 As shown in FIG. 9, the AAUs are not necessarily aligned on the audio PES
2 packet boundaries in the elementary stream. There may be fractions of an AAU at the
3 beginning 116 and/or end 117 of the PES packet payload. The parsing and the
4 reformatting operations take into account this non-alignment of the AAUs with the PES
5 packet boundaries. Each AAU, for example, has 576 bytes, and decodes to a 24
6 millisecond APU, for a sampling frequency of 48 kHz and audio bit rate of 192 kbits/sec.
7 Of course, the splicing techniques disclosed here can be used with a variety of sampling
8 rates and audio encoding techniques.

9 One problem with the splicing of transport streams is the elimination of any audio
10 discontinuity at the splice point without causing an excessive or cumulative skew in the
11 audio buffer level or in the alignment of the audio with the corresponding video. In
12 general, there will be no alignment of the VPUs and the APUs because the audio and
13 video frame durations are substantially incommensurate. For example, an MPEG-2 TS
14 encoding an NTSC television program with an audio sampling frequency of 48 kHz and
15 audio bit rate of 192 kbits/sec will have a video frame duration (VPU) of 1/29.97 sec. and
16 an audio frame duration (APU) of 24 msec. In this example, the start of a VPU will be
17 aligned (in presentation time) with the start of an APU possibly at the beginning of a
18 stream and then only at multiples of 5 minute increments in time. This implies that later
19 they will not be aligned again for all practical purposes.

20 The splicing point between two MPEG-2 Transport Streams is naturally defined
21 with respect to VPUs. The splicing point, for example, occurs at the end of the VPU for
22 an Out Point (I or P frame) in the first TS, and at the beginning of the VPU for an In

1 Point (I frame of a closed GOP) in the second TS. For splicing, the time base of the
2 second TS is shifted to achieve video presentation continuity.

3 Because the AAUs are usually not aligned with the VPU's, there is an issue with
4 respect to the selection of AAUs to be included in the spliced TS. In general, audio
5 truncation (i.e., positioning of the cut with respect to the stream of AAUs in the first and
6 second TS) should always be done at the AAU boundaries. Fractional AAUs are useless
7 because the audio encoding algorithm is such that only whole AAUs can be decoded.
8 Audio truncation for the ending stream should be done with respect to the end of its last
9 VPU's presentation interval. Audio truncation for the beginning stream should be done
10 relative to the beginning of its first VPU's presentation interval. These general rules,
11 however, are insufficient to precisely specify which AAUs should be selected near the cut
12 for inclusion in the spliced TS.

13 A more precise set of rules for selection of AAUs near the cut takes into
14 consideration the concept of the "best aligned APU" and also takes into consideration the
15 audio buffer level that would be expected in the beginning (i.e., second) stream absent
16 splicing. The "best aligned final APU" of the ending (i.e., first) stream is defined as the
17 APU whose presentation interval ends within one APU interval centered about the time
18 of the cut. The "best aligned initial APU" of the beginning (i.e., second) stream is
19 defined as the APU whose presentation interval starts within one APU interval centered
20 about the time of the cut. As shown in the logic table of FIG. 10, there are eight possible
21 cases that can be identified in terms of the "best aligned final APU," the "best aligned
22 initial APU," and the presence of an audio gap or an audio overlap with respect to these

1 best aligned APUs after the alignment of the VPUs of first and second streams at the cut
2 point.

3 In FIG. 10, the APU duration is assumed to be 24 msec only for illustrative
4 purposes without loss of generality. The eight cases are shown in FIGS. 11A, 12A, 13A,
5 14A, 15A, 16A, 17A, and 18A, and corresponding splicing solutions are shown in FIGS.
6 11B, 11C, 12B, 13B, 14B, 15B, 16B, 17B, 17C, and 18B. FIGS. 11B and 11C show
7 alternative solutions, and FIGS. 17B and 17C show alternative solutions. In FIGS. 11A
8 to 18B, VPU_k designates the VPU of the Out-Point, APU_j designates the best aligned
9 final APU, VPU_n designates the VPU of the In-Point, and APU_m designates the best
10 aligned initial APU. Presentation time increases from left to right in the figures, and the
11 bold dashed line is the cut line at which the beginning presentation time of VPU_n
12 becomes aligned with end presentation time of VPU_k .

13 The decoding logic of FIG. 10 can be implemented in software instructions for
14 computing delta values, where delta 1 is computed as the end of the presentation time of
15 the last VPU of the first stream minus the presentation time of the end of the best aligned
16 final APU of the first stream. The best aligned final APU can be found by computing
17 such a delta for each APU in the first stream around the time of the cut, and selecting the
18 APU having such a delta that is within plus or minus one-half of the APU interval. Delta
19 2 is computed as the beginning of the presentation time interval of the first VPU of the
20 second stream minus the presentation time of the beginning of the best aligned initial
21 APU of the second stream. The best aligned initial APU can be found by computing such
22 a delta for each APU in the second stream around the time of the cut, and selecting the
23 APU having such a delta that is within plus or minus one-half of the APU interval.

1 The decoding logic of FIG. 10 is acceptable when the expected mean audio buffer
2 level would be neither high nor low in the second stream absent splicing (i.e., in the
3 original form of the second stream). When such a mean audio buffer level would be high
4 or low for the second stream, additional solutions may be appropriate, as will be
5 described below with reference to FIGS. 27 to 35.

6 Except for the cases in FIGS. 11A and 17A, splicing involves truncating the first
7 audio stream at the end of the best aligned final APU, and starting the second audio
8 stream at the best aligned initial APU. The presentation time stamps of the best aligned
9 initial APU and all following APUs from the second stream are re-stamped so that they
10 follow next in sequence after the best aligned final APU. Since presentation time stamps
11 are not provided for each AAU but rather specified in the header field of audio PES
12 packets for the first AAU commencing in the payload of the PES packet, the above
13 mentioned re-stamping is achieved by modifying only these specified presentation time
14 stamps. Further processing is required at the elementary stream level for modifying the
15 audio PES packet carrying the best aligned final APU, and modifying the audio PES
16 packet carrying the best aligned initial APU. The audio PES packet carrying the best
17 aligned final APU is modified by truncation of AAU data after the AAU associated with
18 the best aligned final APU, and modifying the PES packet size (in the corresponding PES
19 packet header field) accordingly. The audio PES packet carrying the best aligned initial
20 APU is modified by deleting the AAU data preceding the AAU associated with the best
21 aligned initial APU, and modifying the PES packet size (in the corresponding PES packet
22 header field) accordingly. In addition and as mentioned above, the audio PES packet
23 carrying the best aligned initial APU and all subsequent audio PES packets are modified

1 by re-stamping their PTS values to follow in sequence from the PTS value of the audio
2 PES packet carrying the best aligned final APU. The cases in FIGS. 11A and 17A
3 involve similar truncation and modification operations, but in these cases either an
4 additional APU is included in between the best aligned APUs (case of FIG. 11A) or one
5 of the best aligned APUs is omitted (case of FIG. 17A). For the eight cases of audio
6 splicing identified in FIG. 10, it is possible to construct a spliced audio elementary stream
7 with no holes and no audio PTS discontinuity. As a consequence, an audio/video skew in
8 presentation time of magnitude at most half of an APU duration will be introduced
9 following the cut point in the spliced stream. This audio splicing technique can be
10 repeated any number of times with neither a failure to meet its structural assumptions nor
11 a degradation in this audio/video skew performance. The A/V skews introduced by the
12 multiple splices do not accumulate. Irrespective of the number of consecutive splices, the
13 worst audio/video skew at any point in time will be half of the APU duration. At each
14 splice point, at the termination of the APUs and VPU of the first stream, the total audio
15 and video presentation durations up to that point will be almost matching each other, i.e.,
16 $|\text{video_duration} - \text{audio_duration}| \leq (1/2) \text{APU_duration}$. Therefore always the proper
17 amount of audio data will be provided by the audio splicing procedure described above.
18 The resulting audio stream is error-free and MPEG-2 compliant.

19 The audio and video elementary streams must be recombined around and
20 following the splice point. This is conveniently done by reformatting of spliced
21 Transport Stream around and following the splice point. The truncation of the final PES
22 packet of the first audio stream will typically necessitate the insertion of some adaptation
23 field padding into its last transport packet. The deletion of some AAU data from the

1 beginning of the second audio stream's initial PES packet will typically necessitate the
2 editing of at most two audio transport packets.

3 In any MPEG-2 Transport Stream, the audio bit rate, over the span of a few VAU
4 durations, is substantially constant. The VAUs, however, are of varying sizes. Therefore
5 the relative positions of VAUs and AAUs associated with VPUs and APUs almost
6 aligned in time cannot be maintained constant. Almost always it is the case that the
7 AAUs are significantly delayed with respect to the corresponding VAUs for which the
8 decoded representations are almost synchronous. Therefore, splicing to achieve the
9 solutions for the cases of FIGS. 11A to 18A also involves transport packet buffering and
10 re-multiplexing. The delayed audio packets near the Out Point in the first TS stream are
11 temporarily stored in a buffer when the first TS stream is truncated based on the VAU of
12 the Out Point. Also, the spliced TS is reformatted by deletion of some obsolete audio
13 packets at the beginning of the second stream around the In Point, and repositioning of
14 some audio packets of the first stream just following the Out Point into the spliced TS.

15 With reference to FIG. 19, there is shown a top-level flow chart of the preferred
16 procedure for splicing MPEG Transport Streams. At least the portions of a first and
17 second MPEG TS stream around the Out Point and In Point, respectively, are assumed to
18 be stored in a buffer. The stored MPEG TS data for the first stream will be referred to as
19 a first clip, and the stored MPEG TS data for the second stream will be referred to as a
20 second clip.

21 In a first step 121, the splicing procedure receives an indication of a desired end
22 frame of the first clip and a desired start frame of the second clip. Next, in step 122, the
23 splicing procedure finds the closest I frame preceding the desired start frame to be the In

1 Point for splicing. In step 123, a video splicing subroutine is invoked, as further
2 described below with reference to FIGS. 23 to 24. In step 124, an audio splicing
3 subroutine is invoked, as further described below with reference to FIGS. 25 to 26.
4 Finally, in step 125, the concatenation of the first clip up to about the Out Point and the
5 second clip subsequent to about the In Point is re-formatted, including re-stamping of the
6 PTS and PCR values for the audio and video.

7 Considering now video splicing, the splicing procedure should ensure the absence
8 of objectionable video artifacts, preserve the duration of the spliced stream, and if
9 possible, keep all of the desired frames in the spliced stream. The duration of the spliced
10 stream should be preserved in order to prevent any time drift in the scheduled play-list.
11 In some cases, it is not possible to keep all of the original video frames due to buffer
12 problems. In such a case, one or more frames of the clip are replaced by frozen frames,
13 and this frame replacement is made as invisible as possible.

14 Management of the video buffer is an important consideration in ensuring the
15 absence of objectionable video artifacts. In a constant bit rate (CBR) and uniform picture
16 quality sequence, subsequent pictures typically have coded representations of drastically
17 different sizes. The encoder must manage the decoder's buffer within several constraints.
18 The buffer should be assumed to have a certain size defined in the MPEG-2 standard.
19 The decoder buffer should neither overflow nor underflow. Furthermore, the decoder
20 cannot decode a picture before it receives it in full (i.e. completely). Moreover, the
21 decoder should not be made to "wait" for the next picture to decode; this means that
22 every 40 ms in PAL and 1/29.97 second in NTSC, the decoder must have access to a full
23 picture ready to be decoded.

1 The MPEG encoder manages the video decoder buffer through decode time
2 stamps (DTS), presentation time stamps (PTS), and program clock reference (PCR)
3 values. With reference to FIG. 20A, for example, there is shown the video buffer level
4 during the playing of a first clip. The x-axis represents the time axis. The video buffer
5 level initially increases in a linear fashion over a segment 131 as the buffer is loaded at a
6 constant bit rate. Then over a time span 132, video data is displayed at frame intervals,
7 and the buffer is replenished at least to some extent between the frame intervals. At a
8 time T_e , the last video frame's data is finished being loaded into the video buffer. Then
9 the video buffer is periodically depleted to some extent at each subsequent video frame
10 interval, and becomes emptied at a time DTS_{L1} .

11 FIG. 20B shows the video buffer level for a second clip. The video buffer begins
12 to receive video data for the second clip at a time PCR_{e2} . (PCR_{e2} is extrapolated from the
13 value of the most recent received genuine PCR record, to the first byte of the picture
14 header sync word of the first video frame in the clip to start. The extrapolation adjusts
15 this most recently received genuine PCR record value by the quotient of the displacement
16 in data bits of the clip from the position where it appears in the second clip to the position
17 at which video data of the first frame of the second clip begins, divided by the data
18 transmission bit rate for transmission of the clip to the decoder.) The video buffer level
19 initially increases in a linear fashion over a segment 134 as the buffer is loaded at a
20 constant bit rate. However, the slope of the segment 134 in FIG. 20B may be
21 substantially different from the slope of the segment 131 in FIG. 20A. In each case, the
22 slope of the segment is proportional to the bit rate at which the data is loaded into the
23 video buffer. As shown, the video data of the second clip is received at the video buffer

1 at a higher bit rate than the video data of the first clip. At a time DTS_{F2} , the first frame of
2 the second clip is decoded as more video data from the second clip continues to flow into
3 the video buffer.

4 When splicing the end of the first clip of FIG. 20A to the beginning of the second
5 clip of FIG. 20B, there will be a problem of video buffer management if duration of time
6 $DTS_{L1}-T_e$ is different from the duration of time $DTS_{F2}-PCR_{e2}$ minus one video frame
7 (presentation) interval. Because the time PCR_{e2} must just follow T_e , there will be a gap
8 in the decoding and presentation of video frames if $DTS_{F2}-PCR_{e2}$ is substantially greater
9 than $DTS_{L1}-T_e$ plus one video frame interval. In this case, the buffer will not be
10 sufficiently full to begin decoding of the second clip one video frame interval after the
11 last frame of the first clip has been decoded. Consequently, either the second clip will be
12 prematurely started to be decoded or the decoder will be forced to repeat a frame one or
13 more times after the end of the display of the last frame from the first clip to provide the
14 required delay for the second clip's buffer build-up. In the case of a premature start for
15 decoding the second clip, a video buffer underflow risk is generated. On the other hand,
16 in case of repeated frames, the desired frame accuracy for scheduled play-lists is lost
17 besides the fact that a precise timing adjustment can neither be achieved through this
18 procedure.

19 If $DTS_{F2}-PCR_{e2}$ is substantially less than $DTS_{L1}-T_e$ plus one video frame interval,
20 then the decoder will not be able to decode the first frame of the second clip at the
21 specified time DTS_{F2} because the last frame of the first clip will not yet have been
22 removed from the video buffer. In this case a video buffer overflow risk is generated.
23 Video buffer overflow may present a problem not only at the beginning of the second

clip, but also at a subsequent location of the second clip. If the second clip is encoded by an MPEG-2 compliant encoder, then video buffer underflow or buffer overflow will not occur at any time during the decoding of the clip. However, this guarantee is no longer valid if the $DTS_{F2}-PCR_{e2}$ relationship at the beginning of the second clip is altered. Consequently, to avoid buffer problems, the buffer occupancy at the end of the first clip must be modified in some fashion. This problem is inevitable when splicing between clips having significantly different ending and starting buffer levels. This is why SMPTE has defined some splice types corresponding to well-defined buffer levels.

In order to seamlessly splice the first clip of FIG. 20A to the second clip of FIG. 20B, the content of the first clip (towards its end) is modified so that PCR_{e2} can just follow T_e (by one byte transmission time) and DTS_{F2} can just follow DTS_{L1} (by one video frame presentation interval). FIG. 21 shows the video buffer level for the splicing of the first clip to the second clip in this fashion. The content around the end of the first clip has been modified to provide a buffer emptying characteristic shown in dashed lines, such as the line segments 136, so that the buffer is emptied sooner of video data from the first clip. In particular, this is done by replacing a frame loaded into the video buffer over an interval 137 with a "freeze frame" having a selected amount of video data. The position of DTS_{L1} has not changed, the position of DTS_{F2} is one video frame interval after DTS_{L1} , and the relationship $DTS_{F2}-PCR_{e2}$ is unchanged, but the position of T_e has been moved to T_e' in order to achieve the desired conditions for seamless video splicing.

FIG. 22 shows a flow chart of a seamless video splicing procedure that obtains the desired conditions just described above. In a first step 141, the first DTS of the second clip is anchored at one frame interval later than the last DTS of the first clip in order to

1 prevent a video decoding discontinuity. Then, in step 142, the procedure branches
2 depending on whether the PCR extrapolated to the beginning frame of the second clip
3 falls just after the ending time of the first clip. If so, then the splice will be seamless with
4 respect to its video content. Otherwise, the procedure branches to step 143. In step 143,
5 the content of the first clip is adjusted so that the PCR extrapolated to the beginning
6 frame of the second clip falls just after the ending time of the first clip. Therefore the
7 desired conditions for seamless video splicing are achieved.

8 With reference to FIG. 23, there is shown a more detailed flow chart of a seamless
9 video splicing procedure. In a first step 151, the procedure inspects the content of the
10 first clip to determine the last DTS/PTS of the first clip. This last DTS/PTS of the first
11 clip is designated DTS_{L1} . Next, in step 152, the procedure inspects the content of the first
12 clip to determine the time of arrival (T_e) of the last byte of the first clip. In step 153, the
13 procedure adds one frame interval to DTS_{L1} to find the desired first DTS location for the
14 second clip. The sum, designated DTS_{F1} , is equal to $DTS_{L1} + 1/FR$, where FR is the video
15 frame rate. In step 154, while keeping the DTS-PCR_e relationship unaltered, the
16 procedure finds the time instant, designated T_S , at which the first byte of the second clip
17 should arrive. This is done by calculating $T_{START} = DTS_{F2} - PCR_{e2}$, and $T_S = DTS_{F1} - T_{START}$.

18 Continuing in FIG. 24, in step 155, execution branches depending on whether T_S
19 is equal to T_e plus 8 divided by the bit rate. If not, then the clips to be spliced need
20 modification before concatenation, and execution branches to step 156. In step 156,
21 execution branches depending on whether T_S is less than T_e plus 8 divided by the bit rate.
22 If not, then there is an undesired gap in between the clips to be spliced, and execution
23 branches to step 157. In step 157, null packets are inserted into the clips to be spliced to

1 compensate for the gap. The gap to be compensated has a number of bytes, designated
2 G_r , equal to $(T_s - T_e)(\text{BIT RATE})/8$ minus one. If in step 156, T_s is less than T_e plus 8
3 divided by the bit rate, then execution continues from step 156 to step 158 to open up a
4 certain amount of space in the first clip to achieve $T_s = T_e + 8/(\text{BIT RATE})$. The number of
5 bytes to drop is one plus $(T_e - T_s)(\text{BIT RATE})/8$. If possible, the bytes are dropped by
6 removing null packets. Otherwise, one or if needed more predicted video frames are
7 replaced with smaller, variable-size freeze frames.

8 If in step 155 T_s is found to be equal to T_e plus 8 divided by the bit rate, then
9 execution continues to step 159. Execution also continues to step 159 from steps 157 and
10 158. In step 159, the transport streams from the two clips are concatenated. Finally, in
11 step 160, a subroutine, as described below with reference to FIG. 38, is called to compute
12 a video time stamp offset, designated as V_{offset} .

13 With reference to FIG. 25, there is shown the beginning of a flow chart of an
14 audio splicing procedure. In a first step 171, the procedure finds the audio access unit
15 (AAU) of the first clip best aligned with the end frame of the first clip (in terms of the
16 ending instants of their presentations) after splicing of the video. Then, in step 172, the
17 procedure finds the audio access unit (AAU) of the second clip best aligned with the In
18 Point of the second clip (in terms of the starting instant of its presentation). In step 173,
19 for the second clip the mean audio buffer level, assuming no modification made for
20 splicing, is compared to a high threshold, designated B. (B, for example, has a value of
21 66% of the audio buffer capacity.) If this mean audio buffer level exceeds the high
22 threshold B, then the procedure branches to step 174. In step 174, if the above-defined
23 best aligned AAUs do not achieve a backward skew, then the best aligned AAUs are

1 modified by dropping only one of them in either of the clips to reduce the mean audio
2 buffer level for the second clip. In step 173, if the mean audio buffer level does not
3 exceed the high threshold B, then execution continues to step 175. In step 175, the mean
4 audio buffer level for the second clip, assuming no modification made for splicing, is
5 compared to a low threshold, designated A. (A, for example, has a value of 33% of the
6 audio buffer capacity.) If this mean audio buffer level is less than the low threshold A,
7 then the procedure branches to step 176. In step 176, if the above-defined best aligned
8 AAUs do not achieve a forward skew, then the best aligned AAUs are modified by
9 appending only one extra AAU either after the best aligned AAU in the first clip or
10 before the best aligned AAU in the second clip to increase the mean audio buffer level for
11 the second clip.

12 In general, a forward skew of the AAUs from the second stream by incrementing
13 their presentation time instants tends to increase the mean audio buffer level. Therefore,
14 a forward skew is good if the mean audio buffer level is low for the second stream. A
15 backward skew of the AAUs from the second stream by decrementing their presentation
16 time instants tends to decrease the audio buffer level. Therefore, a backward skew is
17 good if the mean audio buffer level is high for the second stream.

18 In step 175, if the mean audio buffer level is not less than the low threshold A,
19 then the procedure continues to step 177 in FIG. 26. The procedure continues to step 177
20 also after steps 174 and 176. In step 177, the procedure removes all AAUs in the first
21 clip after the best aligned AAU in the first clip, and adjusts the last audio PES packet
22 header in the first clip to reflect the change in its size in bytes after the removal. In FIG.
23 26, step 178, the procedure finds the audio PES packet in the second clip which includes

1 the best aligned AAU in the second clip, and removes all AAUs preceding the best
2 aligned one in this PES packet. Then in step 179, the procedure produces a PES packet
3 header to encapsulate the best aligned AAU and the AAUs after it, and writes the PES
4 packet size into the header. Finally, in step 180, the procedure calculates the required
5 audio PTS offset (A_{offset}) to be used for re-stamping the audio of the second clip.

6 The preferred implementation of the audio splicing routine in FIGS. 26 and 27
7 uses the logic shown in FIG. 27. Depending on whether the mean audio buffer level for
8 the second clip, assuming no modifications are made for splicing, is greater than the high
9 threshold B or less than the low threshold A, the eight cases of FIG. 10 are expanded to
10 sixteen cases. The preferred solutions for these eight additional cases are shown in FIGS.
11 28 to 35. When the mean audio buffer level for the second clip, assuming no
12 modifications are made for splicing, is neither greater than the high threshold B nor less
13 than the low threshold A, then the solutions shown in FIGS. 11 to 18 are immediately
14 applicable.

15 A preferred method of estimating the mean audio buffer level of a clip is to use
16 the product $(PTS_i - PCR_{ei})(\text{BIT RATE})$ as an indication of the audio buffer level. PTS_i
17 denotes the i th audio PTS time stamp, and PCR_{ei} denotes the PCR value extrapolated to
18 the bit position of PTS_i . Because the product $(PTS_i - PCR_{ei})(\text{BIT RATE})$ will fluctuate
19 more rapidly than the mean audio buffer level, the computed values may be processed by
20 a simple digital filter routine to obtain an estimated value of the mean audio buffer level
21 at any point of a clip. Shown in FIG. 36, for example, is a digital filter schematic that
22 includes a single first-order recursive stage 191 for computing an estimate of the mean
23 audio buffer level ABV. The computation includes a scaling of $(PTS_i - PCR_{ei})(\text{BIT$

1 RATE) by a factor of $1/n_{av}$, where n_{av} is the effective number of samples over which the
2 mean is estimated. The scaled value is added to the previous estimate of the mean value
3 of ABV scaled by a "forgetting factor" of $1-1/n_{av}$. The previous value is stored in a
4 register 192. In a similar fashion, an estimate of the variance of the audio buffer level at
5 any point of a clip is computed by similar circuitry or computations depicted in FIG. 36.
6 For example, the estimate of the variance can be computed by a subtractor 193 that
7 calculates the deviation of each sample of $(PTS_i - PCR_{ei})(BIT\ RATE)$ from the estimated
8 mean audio buffer level, a squaring unit 194, and another first-order recursive filter stage
9 generally designated 195.

10 Instead of determining whether the mean audio buffer level is relatively high or
11 low for a clip, a determination can be made as to whether the audio buffer full level (i.e.,
12 audio buffer size) is within a certain number of estimated standard deviations from the
13 estimated mean audio buffer level, or whether the audio buffer empty level (e.g., zero
14 bytes) is within a certain number of estimated standard deviations from the estimated
15 mean audio level. In this case, the certain number can be selected based on the usual
16 statistics of the type of audio encoding that is employed, in order to ensure the absence of
17 audio buffer underflow or overflow within a desired level of confidence. In order to
18 make the comparisons very simple at the time of splicing, the maximum and minimum
19 expected deviations from the estimated average can be computed in advance for each
20 clip. For example, FIG. 37 shows in schematic form the computations necessary to
21 compute the maximum of the estimated mean buffer level AVB plus twice the estimated
22 standard deviation, and to compute the minimum of the estimated mean buffer level AVB
23 minus twice the standard deviation. The box 198, for example, outputs a binary value

To simplify audio buffer management during splicing transients, it is recommended to have the same audio buffer levels at the beginning and at the end of the clips. The case of going from a low to a high audio buffer level is the most problematic, and is addressed by a sufficiently precise mean buffer level estimate for beyond the selected In Point.

9 If there are multiple audio streams for one program, then all of these individual
10 audio streams are processed independently in the fashion described above for a single
11 stream. For example, there could be two stereo audio streams for one program, or four
12 audio streams for quadraphonic sound. The association of the ending (i.e., first) clip and
13 starting (i.e., second) clip audio streams to splice together depends on the PID of the
14 streams after PID re-mapping, if there is PID re-mapping, or on the PID of each stream in
15 the spliced clips, if there is no PID re-mapping. For an audio stream of the ending clip
16 that has no audio stream in the starting clip that can be associated with it, the preserved
17 audio packets are played until the end. This will achieve the best possible alignment
18 between audio and video for the ending clip.

The method used above for seamless audio splicing can also be used for splicing other elementary streams containing encapsulated data. For example, a TS may have additional elementary streams of other data encapsulated in access units such as access units for teletext, closed captioning, VBI, etc. To apply the seamless splicing method to a TS having multiple elementary streams of non-video and non-audio access units, the

1 AU's in each elementary stream are found that are best aligned with the first and last
2 video frames, and an AU sequence over the splice is selected, independent of the content
3 of the other non-video elementary streams. In this case, the method will minimize skew
4 with respect to associated video frames and also prevent accumulation of skew from
5 multiple splices in the TS.

6 With reference to FIG. 38, there is shown a flow chart of a procedure for
7 calculating the video time stamp offset V_{OFFSET} . In a first step 211, the procedure finds
8 the DTS of the last video frame (in decode order) of the first clip. This DTS of the last
9 video frame of the first clip is denoted DTS_{VL1} . Then in step 212, the procedure finds the
10 original DTS of the first frame to be decoded in the second clip. This DTS of the first
11 frame to be decoded in the second clip is denoted DTS_{VF2} . Finally, in step 213, the video
12 time stamp offset V_{OFFSET} is computed as $\text{DTS}_{\text{VL1}} - \text{DTS}_{\text{VF2}}$ plus one video frame duration.

13 With reference to FIG. 39, there is shown a flow chart of a procedure for
14 calculating the audio time stamp offset A_{OFFSET} . In a first step 221, the procedure finds
15 the PTS of the last AAU of the first clip. This PTS of the last AAU of the first clip is
16 denoted PTS_{AL1} . Then in step 222, the procedure finds the original PTS of the first AAU
17 to be decoded in the second clip. This PTS of the first AAU to be decoded in the second
18 clip is denoted PTS_{AI2} . Finally, in step 223, the audio time stamp offset A_{OFFSET} is
19 computed as $\text{PTS}_{\text{AL1}} - \text{PTS}_{\text{AI2}}$ plus one AAU duration.

20 With reference to FIG. 40, there is shown a flow chart of a procedure for
21 calculating the PCR offset $\text{PCR}_{\text{OFFSET}}$. In a first step 231, the procedure finds the
22 extrapolated PCR_e for the last byte of the first clip. This extrapolated PCR_e is denoted
23 PCR_{eL1} . Then in step 232, the procedure finds the original extrapolated PCR_e for the first

1 byte of the second clip. This extrapolated PCR_e is denoted PCR_{eF2} . Finally, in step 233,
2 the PCR offset PCR_{OFFSET} is computed as $PCR_{eL1} - PCR_{eF2}$ plus eight divided by the bit
3 rate.

4 With reference to FIG. 41, there is shown a flow chart of a procedure for re-
5 stamping the time stamps in the portion of the second clip appearing in the spliced
6 transport stream. In step 241, the video time stamp offset V_{OFFSET} is added to the DTS
7 and PTS fields of all video PES packets in the second clip. Next, in step 242, the audio
8 time stamp offset A_{OFFSET} is added to the PTS fields of all audio PES packets in the
9 second clip. In step 243, the PCR time stamp offset PCR_{OFFSET} is computed by invoking
10 the subroutine of FIG. 40. In step 244 the PCR_{OFFSET} is added to all PCR records in the
11 second clip. In step 245 the PID fields of the TS packets of the various streams in the
12 second clip are re-stamped based on their associations with the various streams of the
13 first clip. Finally, in step 246, the continuity counter fields of the TS packets of the
14 various streams are re-stamped in the second clip so as to achieve stream continuity from
15 the first clip to the second clip.

16 In order to solve certain buffer problems and also to avoid artifacts in case of clips
17 starting with an open GOP, it sometimes becomes necessary to remove some frames. If
18 these frames are removed from the stream without any replacement, a "hole" in the frame
19 presentation time sequence will be generated. In this case, the result depends on the
20 decoder implementation (i.e. on how a particular decoder handles this situation). For
21 example, some decoders try to correct the problem by themselves. More precisely, they
22 do not take the recorded DTS values into account and continue decoding the frames they
23 have received until they possibly enter an underflow state. The observed result is a freeze

1 of the scene which occurs some frames after the splicing point (sometimes 10 frames). In
2 other decoders the consequences could be more catastrophic.

3 To avoid any unpleasant effect in a controlled fashion, the frames which cannot
4 be decoded are replaced by encoded frozen frames. These frames are encoded such that
5 they effectively repeat a previous frame in the decoding order. They can be either B-
6 frames or P-frames. The frozen frame implementation relies on null motion vectors and
7 no coded transform coefficients. Consequently, these frames are completely MPEG-2
8 compliant and the decoder doesn't encounter any discontinuity in the stream.

9 With these frozen frames, decoder freeze can be controlled to make the visual
10 perception cleaner. There are three different types of encoded frozen frames that can be
11 generated for this purpose. These three types are a P-frame repeating the previous I or P
12 frame (in display order), a B-frame repeating the previous I or P frame (in display order),
13 and a B-frame repeating the following I or P frame (in display order). Moreover, any
14 frozen frame should not be separated from the frame it is repeating by some live (i.e. non-
15 frozen) frames in display order. To avoid any undesirable flickering effect due to the
16 presence of two fields within an interlaced frame, the frozen frames are generated using
17 the dual motion prediction type which allows the encoding of one field by extrapolation
18 (prediction) from the dual field.

19 With reference to FIG. 42, there is shown a diagram of the pixels in a video frame
20 250. According to the MPEG video encoding standard, the video frame can be
21 subdivided into a rectangular array of macroblocks, where each macroblock 251 includes
22 a square array of pixels. Pixels on the lower right and lower borders of a frame that do
23 not fit into full size macroblocks are handled as follows. The frame horizontal and

1 vertical sizes are completed to the nearest integer multiples of macroblock horizontal and
2 vertical sizes by right-most column and lower-most row repetitions respectively. The
3 MPEG standard also permits slices, or linear arrays of contiguous macroblocks, to be
4 defined, with the maximum sized slices including an initial macroblock in a left-most
5 column and a final macroblock in a right-most column. For example, a maximum size
6 slice 255 is shown including all of the macroblocks in the third row of the macroblock
7 matrix. A large number of consecutive macroblocks in a slice can be very efficiently
8 encoded by a command to skip that number of macroblocks immediately after the initial
9 macroblock in the slice. In case of a skip, the encoding information (i.e., the motion
10 vectors and quantized DCT coefficients for the prediction error) is common to all skipped
11 macroblocks and therefore is not repeated for each skipped macroblock.

12 It is possible to encode a "freeze frame" in various ways, such that the encoding
13 of the "freeze frame" will result in a selected variable size. The smallest freeze frame
14 will define the maximum number of skipped macroblocks and maximum size slices, and
15 a null set of DCT coefficients for the prediction residual and zero valued displacement
16 vectors. The largest freeze frame will define, for each of the non-skipped macroblocks, a
17 set of zero valued DCT coefficients for the prediction residual and zero valued
18 displacement vectors. Freeze frames of intermediate sizes can be defined by using
19 different numbers of skipped macroblocks, and then various sizes of slices of
20 macroblocks. Also, a slight adjustment can be made by padding. Padding is done by
21 placing some stuffing bytes in the adaptation field (see FIG. 5).

22 With reference to FIG. 43, there is illustrated a problem of non-obsolete audio TS
23 packets 260 that follow in the first clip after the end 261 of the video TS packet for the

1 Out Point, and null TS packets 262 and obsolete audio packets 263 in the second clip
2 after the beginning of the video TS packet for the In Point. It is desired to replace as
3 many of the null TS packets 262 and obsolete audio packets 263 as possible with the non-
4 obsolete audio packets. If any of the non-obsolete audio packets from the first clip
5 cannot be repositioned into existing packet positions in the second clip after the
6 beginning of the video TS packet for the In Point, then the placement of these remaining
7 non-obsolete audio TS packets may affect the $DTS_{F2}-PCR_{e2}$ relationship of the In Point
8 of the second clip or the $T_S = T_e + 8/(\text{bit rate})$ relationship that needs to be satisfied for
9 seamless video splicing. In particular, the number of bits of the remaining non-obsolete
10 audio packets must either fit in the gap that needs to be compensated in step 157 of FIG.
11 24, or will require additional space to be opened up in the clip in step 158 (for example
12 by reducing the size of a freeze frame or increasing the number of video frames in the
13 first clip that must be replaced by freeze frames) to make room for them.

14 With reference to FIG. 44, there is shown a procedure of a re-formatting operation
15 that solves the problem of the non-obsolete audio TS packets 260 that follow in the first
16 clip after the end 261 of the video TS packet for the Out Point. In a first step 271, the
17 procedure determines the number (designated "j") of non-obsolete audio packets in the
18 first TS stream or clip following the end of the video at the Out Point, and the total
19 number (designated "k") of null packets and obsolete audio packets in the second TS
20 stream or clip following the beginning of video at the In Point and up to the first non-
21 obsolete audio packet in the second TS. Next, in step 272, the procedure replaces any of
22 the "k" null packets or obsolete audio packets in the second TS stream with
23 corresponding ones of the "j" non-obsolete audio packets in the first TS stream,

1 beginning with the most advanced in time packets. Then, in step 273, the procedure
2 branches depending on whether or not "j" is greater than "k". If "j" is not greater than
3 "k", then all of the non-obsolete audio packets following the Out Point from the first TS
4 stream have been inserted into the second TS stream following the In Point so that they
5 no longer constitute a problem for the seamless video splicing. In this case, execution
6 branches to step 274 to change any remaining obsolete audio packets to null TS packets,
7 and the reformatting procedure of FIG. 44 is finished.

8 If "j" is greater than "k", execution continues from step 273 to step 275. In step
9 275, for the remaining (j-k) non-obsolete audio packets from the first stream, the
10 procedure creates (j-k)*188 bytes of additional space for them in the spliced TS stream
11 prior to the video for the Out Point. This additional space must be generated so as to
12 maintain the $T_s = T_e + 8 / (\text{bit rate})$ condition of FIG. 24 for seamless video splicing. This
13 additional space can be entirely or partially provided by the space of the null TS packets
14 created in step 157, in which case these null TS packets are replaced with non-obsolete
15 audio packets. Any remaining ones of the non-obsolete audio packets are placed into the
16 space opened up by reducing the space taken by the video packets in the first stream prior
17 to the Out Point. After step 275, the re-formatting routine of FIG. 44 is finished.

18 The reformatting of the spliced TS stream after concatenation also includes steps
19 to ensure the continuity of associated individual streams across the splice point. The
20 same program specific information (PSI) tables must occur before and after the splicing
21 point. This is achieved by re-stamping all of the program identification indices (PIDs)
22 within the second clip with the associated stream PIDs of the first clip. The program
23 identification indices must be the same for the different component streams which form a

1 continuation before and after the splicing points. In addition, the continuity counter
2 sequence for each elementary stream must be evolving continuously across the splicing
3 point. Therefore, typically all of the continuity counter values are re-stamped for each
4 transport packet of the second stream.

5 There can also be a need for some further reformatting to permit the In Point to be
6 an I frame of an open GOP, and to select where freeze frames should be inserted in the
7 last GOP before the Out Point. When the clip to decode and present for viewing starts
8 with an open GOP, some B-frames will typically contain references to a frame that was in
9 the previous GOP at the encoding time. These reference frames are not present in the
10 new stream. So, it is not possible to play these B frames without artifacts. They must be
11 removed. However, in order to keep an MPEG-2 compliant stream and also to preserve
12 frame accuracy, these B frames are replaced by encoded frozen frames referring to a
13 previous (in display order) I or P frame. As these B frames sent after the first I frame of
14 the clip to start, are presented before it, the freeze will occur just at the splicing. The last
15 anchor frame of the completed clip is repeated one or several times, but the new clip
16 starts without any artifacts.

17 At the end of a clip, before decoding the last GOP to play, the procedure
18 determines which changes are to be performed in this GOP to avoid buffer problems. To
19 do this, the procedure accesses the following data:

20

- 21 - the last GOP size (in bytes)
- 22 - the last GOP size (in frames)

- 1 - the DTS-PCR_e at the beginning of this GOP (i.e. for its first frame) and
- 2 the ending delay $T_{\text{end}} = \text{DTS}_{L1} - T_e$ at the end of this GOP which can be
- 3 computed.
- 4 - the number of frames to play from this GOP which is not necessarily
- 5 equal to the full GOP size.

6

7 To rebuild this GOP, the procedure has access to the GOP structure and the size of each

8 frame. So, the last GOP is read in full into the memory. This is done only if the

9 procedure needs to terminate with an incomplete GOP. If a play-at-time interrupt arrives

10 during playing a clip, the procedure determines in advance the number of frames

11 remaining before the transition to the next clip to prepare the GOP.

12 The frames to be replaced by encoded frozen frames depend on the GOP

13 structure. This point will be illustrated by examples.

14

15 Example 1: Incomplete GOP with 3n frames.

16

17 Transport order:	I	B	B	P	B	B	P	B	B	P	B	B
18 Display order:	2	0	1	5	3	4	8	6	7	11	9	10

19

20 Case 1: The procedure has to play 3n frames. The procedure takes the first 3n

21 frames without any problem since the set of the first 3n frames in the transport order is

22 the same as the set of the first 3n frames in display order as shown above.

23

1 Example 2: Incomplete GOP with $3n+1$ frames. (Case of $3n+1=7$ is illustrated.)

2

3

4 Transport order: I B B P B B Pff

5 Display order: 2 0 1 5 3 4 6

6

7 Case 2: The procedure has to play $3n+1$ frames. Then the procedure replaces the
8 last frame by a frozen frame as shown above. Pff implements a freeze of P5.

9

10 Example 3: Incomplete GOP with $3n+2$ frames. (Case of $3n+2=8$ is illustrated.)

11

12

13 Transport order: I B B P B B Pff Bff

14 Display order: 2 0 1 5 3 4 7 6

15

16 Case 3: The procedure has to play $3n+2$ frames. Then the procedure inserts two
17 frozen frames as shown above. Both Bff and Pff implement freeze of P5.

18

19

20 Example 4: Structurally closed IBBP... GOP.

21

22 Transport order: I P B B P B B P B B P B B

23

1 Display order: 0 3 1 2 6 4 5 9 7 8 12 10 11

2

3

4 Within this GOP structure playing $3n+1$ frames is trivial and can be achieved
5 without any freeze frames. Playing $3n+2$ frames can be achieved by freezing just one
6 frame as illustrated below for the case of $3n+2=8$:

7

8

9 Transport order: I P B B P B B Pff

10 Display order: 0 3 1 2 6 4 5 7

11

12 where Pff implements a freeze of P6. Similarly, playing $3n$ frames can be
13 achieved by freezing two frames as illustrated below for the case of $3n=9$:

14

15 Transport order: I P B B P B B Pff Bff

16 Display order: 0 3 1 2 6 4 5 8 7

17

18 where Pff and Bff both implement a freeze of P6.

19

20 These changes are applied before taking into account the buffer level. They provide a
21 modified GOP tailored for achieving the desired temporal frame accuracy. After these
22 transformations related to the GOP structure are performed, the buffer level (DTS-PCR)
23 at the end of this GOP is computed based on the resultant (i.e. modified) GOP structure.

1 If the new GOP's (i.e. the first GOP of the clip to start) buffer level is too high
2 and if there is no padding bandwidth available in the end of the first clip, then additional
3 frames are replaced by encoded frozen frames, starting from the last one in transport
4 order and proceeding one frame at a time (towards the beginning of the first clip) until the
5 GOP size becomes small enough.

6 These GOP transformations can be done in advance, as soon as the number of
7 frames to play in the current clip becomes known. This means that, if there is a play-at-
8 time command to start the next clip, then the timer must expire late enough to allow the
9 computation of frames remaining to play and also the preparation of the last GOP.

10 With reference to FIG. 45, it is possible to pre-compute metadata that can speed
11 up the process of seamless splicing. This is especially useful when the seamless splicing
12 must be done on the fly, during real-time delivery of a TS stream. For example, a stream
13 server of the video file server 20 of FIG. 1 performs metadata computation (281 in FIG.
14 45) when the file server records the MPEG TS stream in a MPEG file 282. As the MPEG
15 TS data 285 becomes recorded in the MPEG file 282, the metadata is recorded in a
16 header of the MPEG file. The header, for example, is a first megabyte of random-
17 accessible address space in the file. Preferably, the metadata includes some metadata 283
18 associated with the clip as a whole, and metadata 284 associated with the individual
19 GOPs. Preferably, the metadata 284 associated with the individual GOPs is stored in a
20 GOP index table.

21 The metadata 283 associated with the clip as a whole includes a program number,
22 the video frame rate, status of the clip, the number of GOPs in the clip, stream identifiers
23 for the various elementary streams in the TS, a byte index indicating a beginning position

1 of the clip in the file, and a byte index indicating an ending position of the clip in the file.
2 This metadata 283 is stored in the file header, just before the GOP index 284.

3 The GOP index table may store the values of predefined attributes of each GOP
4 included in the MPEG TS data. However, it is desirable to permit any number of the
5 GOPs having recorded MPEG TS data 285 to have GOP index table entries that are
6 empty of valid metadata values. Therefore, the metadata computation 281 can be
7 suspended whenever computational resources are needed for higher priority tasks.

8 FIG. 46 shows a preferred format for the GOP index table 284. The GOP index
9 table includes an entry for each GOP having MPEG TS data recorded in the MPEG file.
10 Each entry is a row in the table, and the table is indexed implicitly by the GOP number.
11 Each entry includes a frame number which is the frame number of the first video frame in
12 the GOP, a pointer to the beginning of the MPEG TS data for the GOP, a set of flags for
13 the GOP, and other GOP attributes. One of the flags for the GOP, or alternatively a sign
14 bit of the frame number or the presence of a predefined reserved value for the frame
15 number, indicates whether or not the GOP entry is valid. The GOP attributes include, for
16 example, the maximum bit rate, the average bit rate, the AAU size in bytes, the APU
17 duration in seconds, the audio PES packet starting locations, the AAU starting locations,
18 the AAU PTS values, the PCR_e of the first video frame, and a flag indicating whether or
19 not the GOP is open or closed.

20 The GOP index table can be decimated to reduce its size. For example, if so
21 much MPEG TS data becomes written to the MPEG TS file that there is insufficient
22 space in the 1 megabyte header to hold entries for all of the GOPS, then the GOP index
23 can be decimated by a factor of two by writing the content of the GOP entry for GOP no.

1 2 over the GOP entry for GOP no. 1, writing the content of the GOP entry for GOP no. 4
2 over the GOP entry for GOP no. 2, writing the content of the GOP entry for GOP no. 6
3 over the entry for GOP no. 3, etc.

4 With reference to FIG. 47, there is shown a flow chart for GOP index decimation.
5 In a first step 331, before computing attributes for any GOP, a GOP decimation factor is
6 set to one in the metadata for the clip. (This decimation factor, for example, is used to
7 find a GOP table index for a given GOP number by dividing the given GOP number by
8 the decimation factor.) Computation of attribute values for the GOPs found in an
9 ingested TS and the writing of those attribute values to respective entries in the GOP
10 index continues in step 332 until the end of the GOP index is reached in step 333. Then
11 the procedure continues to step 334 where the GOP index is decimated by a factor of two.
12 Finally, the decimation factor is increased by a factor of two, and the procedure loops
13 back to step 332.

14 Some of the metadata is of high priority and some of the metadata is of lower
15 priority. In the absence of sufficient computational resources, the high priority metadata
16 can be pre-computed without pre-computing the lower priority metadata. For example,
17 the frame rate for the clip is a high priority item but the number of frames in the clip is a
18 low priority item. The frame number and the pointer to the corresponding MPEG TS
19 data (i.e., a byte index) are high priority GOP attributes. The flag indicating whether or
20 not the GOP is open or closed is a low priority item. In the situation where it is possible
21 that a GOP entry will include the high priority items but not the low priority items, the
22 low priority items are encoded with an indication of whether they are valid or not. This

1 can be done by initially setting the low priority items to predetermined invalid values
2 indicating that valid attribute values are not yet computed.

3 With reference to FIG. 48, there is shown a flow chart of metadata computations
4 for a next GOP processed in a TS. In a first step 341, if resources available for
5 computing high priority metadata are not presently available, then the computations for
6 the GOP are terminated. Otherwise, the procedure continues to step 342, where the high
7 priority metadata is computed for the GOP. Then, in step 343, if resources for computing
8 low priority metadata are not available, then the computations for the GOP are
9 terminated. Otherwise, the procedure continues to step 344, where the low priority
10 metadata is computed for the GOP.

11 The GOPs in a TS can be fixed size (same size throughout the TS) or variable size
12 in terms of the number of video frames they contain. If the GOPs are of a fixed size, then
13 each has an integral number of "n" frames. In this case, assuming that the first frame
14 number in the TS is "m", then the number of the GOP containing a specified frame "p"
15 can be calculated as the integer quotient of (p-m)/n plus one. If the GOPs are of variable
16 size, then the metadata may include an average GOP size; i.e., an average number of
17 frames per GOP. In this case, to find the GOP containing a specified frame, the GOP
18 number is estimated using the same formula (using the average number of frames per
19 GOP for n), and then the GOP index table is searched in the neighborhood of this GOP
20 for the GOP containing the specified frame number.

21 The metadata contains information on the clip which is used during the play
22 operation to check the buffer levels and to adjust these levels at the splicing time. The
23 fundamental information item of metadata is the difference DTS-PCR_e for each video

1 access unit within the video stream which is representative of the buffer level in the sense
2 described previously. It should be noted that DTS values are defined for I and P frames
3 for which the decoding and presentation times differ since these frames are used as
4 references by other P and B frames. However, for type B frames only PTS is defined
5 which is identical to the DTS of the same frame.

6 A subsection of the metadata includes the following two values:

7
8 First PTS: This is the PTS of the first frame in display order.

9
10 First PCR, ($PCR_{e,0}$): This is a calculated (i.e, extrapolated) PCR value corresponding
11 to the beginning (i.e. the first byte) of the file. This value is computed from the bit-rate,
12 the value of the first genuine PCR record and its byte position within the file.

13
14 Based on these two values, for each I frame the procedure computes both the DTS
15 of this frame and also the PCR_e value corresponding to the beginning of this frame within
16 the file. In order to perform these calculations, the procedure also accesses the frame
17 number (a cumulative frame count from the beginning of the file) and the byte position of
18 the beginning of this frame in the file, both of which are recorded in the GOP index table.

19 The GOP index table forms a major sub-section of the metadata. It is easy to see
20 that assuming one I frame per GOP, the cumulative frame count values at I pictures also
21 become their cumulative temporal references (referring to display order). Then, it is
22 straightforward to calculate a PTS value for each of these I frames assuming a continuous
23 video play-out. Finally, assuming a known uniform GOP structure, these presentation

1 time stamps of I pictures can be easily converted to decoding time stamps based on the
2 principle that the decode time instant of an anchor frame is the same as the presentation
3 time instant of the previous anchor frame. So, the DTS-PCR_e difference can be
4 computed in advance for each I frame of the file and consequently whatever the start
5 position is in a clip for play-out, the required buffer level to be build-up can be known in
6 advance.

7 With reference to FIG. 49, there are shown further details of the components
8 involved in the ingestion of an MPEG TS into a stream server computer 291 for
9 recording in the cached disk array, and for real-time splicing during real-time
10 transmission of an MPEG TS from the cached disk array and from the stream server
11 computer to a destination such as one of the clients (54 in FIG. 1). The stream server
12 computer 291 is interfaced to the network (25 in FIG. 1) via a network interface board
13 292. The network interface board 292, for example, is a DVB board, an ATM board, an
14 Ethernet board, a Fiber Channel board, or a Gigabit Ethernet board. The network
15 interface board 292 performs a direct memory access upon buffers 293 in the random
16 access memory 294 of the stream server computer 291 in order to exchange MPEG TS
17 data with the network (25 in FIG. 1). A software driver 295 for the network interface
18 board 292 initiates the direct memory access transfers. In particular, the software driver
19 295 hands to the network interface board 292 the RAM address range of the data in the
20 buffer for the DMA transfer. Real-time delivery of an MPEG TS stream from the stream
21 server 291 is controlled by a "house" clock signal 55. As shown in FIG. 1, the house
22 clock signal 55 is applied to each of the stream servers 21 and the controller servers 28,

1 29 in the video file server 20. This house clock signal 55 simultaneously interrupts each
2 stream server and controller server at the video frame rate.

3 For DVB (digital video broadcast), data is transmitted upon request. When the
4 stream server is accepting data from an application, the request is produced when a
5 receive buffer becomes available. For ATM (asynchronous transfer mode), the data is
6 transmitted in response to a time interrupt signal. A buffer is scheduled to be available
7 when the interrupt is expected to occur. In either case, when transmitting an MPEG TS,
8 the data must be delivered to ensure that any jitter is within the limit that the MPEG
9 standard imposes on the PCR time values. The PCR values must be accurate within 20
10 cycles of a 27 MHz decoder clock. Moreover, the difference between neighboring PCR
11 values in the TS is kept less than 100 msec; otherwise, the decoder clock will reset.

12 When ingesting an MPEG TS from the network (25 in FIG. 1), once an assigned
13 one of the buffers 293 is filled with MPEG TS data, the software driver 295 inserts a
14 pointer to the filled buffer into a FIFO buffer pointer queue 296. A metadata
15 computation software program module 297 finds that the queue 296 is not empty, and
16 services the queue by obtaining the buffer pointer from the queue and accessing the
17 MPEG TS data in the buffer 293 indicated by the pointer. The metadata computed by the
18 program module 297, for example, is placed in a header of the buffer. When the
19 metadata computation module 297 is finished, it places the buffer pointer in another FIFO
20 buffer pointer queue 298. The queue 298 is serviced by a write access program module
21 299. The write access program module 299 removes the pointer from the queue 298, and
22 then writes the data from the indicated buffer to an MPEG TS file of the file system 300.
23 The file system 300 writes the data to the cached disk array 23 in an asynchronous write

operation to data storage in the cached disk array. The file system maps the address space of each file to one or more 16 megabyte blocks of storage in the cached disk array. (The active one of the controller servers 28, 29 in FIG. 1 has supervisory control over these operations of the stream server computer 291.)

To perform splicing or other real-time MPEG processing during real-time delivery of an MPEG TS to the network (25 in FIG. 1), a read access program module 301 invokes the file system 300 to read the MPEG TS data from an MPEG TS file in the cached disk array 23 in an asynchronous read operation upon data storage in the cached disk array, and the read access program module writes the MPEG TS data into an assigned one of the buffers 293. When the read access program 301 has filled the assigned one of the buffers 293, it places a pointer to the buffer on a FIFO buffer pointer queue 302. An MPEG processing program module 303 services the queue 302. Upon finding that the queue 302 is not empty, the module 303 removes the pointer from the queue 302 and accesses the buffer 293 indicated by the pointer.

For splicing, the MPEG processing module 303 will access two consecutive buffers, one containing a first clip and the other containing a second clip. The splicing procedure modifies the first clip in its assigned buffer so that the first clip will represent the spliced TS. Splicing in real time requires parsing the TS stream in real time for audio PES packet headers, and parsing the audio PES packets in real time for the AAUs. Also the TS stream is parsed in real time to find the GOP header and to extract the display order and type (i.e., open or closed) from the GOP header. The AAUs around the splice point are identified as obsolete or not, the non-obsolete AAUs are reformatted and the obsolete AAUs are eliminated in real time. The TS stream around the splice point is

1 modified in real time for seamless video splicing. The time stamp offsets are computed
2 and the spliced TS stream following the splice point has all of its time stamps and
3 continuity counters re-stamped in real time.

4 When the MPEG processing module 303 is finished with the splicing operation, it
5 places the pointer to the buffer of the spliced TS into yet another FIFO buffer pointer
6 queue 304. The queue 304 is serviced by the software driver. Upon finding that the
7 queue 304 is not empty, the software driver 295 removes the pointer from the queue 304,
8 and causes the network interface board to initiate a direct memory access transfer of the
9 spliced TS from the indicated buffer 293 to the network (25 in FIG. 1). The TS data is
10 buffered from the MPEG processing to the network interface board because the network
11 interface board has priority access to the stream server RAM. (The active one of the
12 controller servers 28, 29 in FIG. 1 has supervisory control over these operations of the
13 stream server computer 291.)

14 It is also possible for the new spliced TS to be stored in the cached disk array 23,
15 with or without concurrent transfer to the network (25 in FIG. 1.) In this case, the
16 software driver 295 passes the buffer pointer from the queue 304 to the queue 296.

17 Overall, it is seen that the buffers 293 function as a kind of carousel to distribute clips and
18 MPEG TS streams data to successive processing, storage, and stream delivery functions,
19 and the MPEG TS streams can be easily edited and spliced in the process.

20 The number of buffers 293 that are allocated for use in the carousel during the
21 reading, writing, or generation of a spliced TS is a function of the bit rate of the TS. A
22 higher bit rate requires more buffers. Each buffer, for example, has 64 kilobytes of
23 memory, and the data rate can range from about 100 kilobits per second to 130 megabits

per second. The buffers smooth out variations in bit rate that are not deterministic in time. The buffer size can be much smaller than a clip, and smaller than a portion of a clip that is needed for splicing. In this case, when splicing a first stream (S_1) to a second stream (S_2), alternate buffers in sequence around the carousel can contain data from the same clip. For example, a first buffer may contain a next-to-last segment of the first clip, a second buffer may contain a first segment of the second clip, a third buffer may contain a last segment of the first clip, and a fourth buffer may a second segment of the second clip.

The metadata computation module 297 parses the content of its assigned buffer. The parsing typically continues from one buffer to a next buffer in the carousel, for the usual case where each buffer has a size smaller than the duration of the TS. The parsing counts frames, builds GOP entries, calculates instantaneous bit rates and other GOP attributes, and looks for error conditions. Each GOP header is parsed for display order and type (i.e., open or closed).

The MPEG processing 303 may use a number of flags. These MPEG processing flags include the following:

- 0x100: re-stamp time records flag

If this flag is set then all of the PCR and DTS/PTS records are recomputed and re-stamped so that they are continuous across splicing transitions.

- 0x200 : discontinuity flag

1

2 If this flag is set, the discontinuity flag of the adaptation field in the TS packet headers is
3 set following the splicing point.

4

5 -0x1000: rate-based padding flag

6

7 This bit is not used by the MPEG processing itself. If padding is necessary since the
8 session bit-rate is greater than the clip bit-rate, the right amount of padding will be
9 inserted in any case. However, it is used by the video service to allow appending clips
10 having a bit-rate smaller than the session bit-rate. If it is not set, the video service allows
11 only clips having the same bit-rate as the current session.

12

13 -0x2000: allow removal of B frames in an open GOP

14

15 If this flag is not set then no frames from any clip can be removed or replaced. This bit
16 must be set only if clips are encoded with an encoder set-up to generate clips that can be
17 spliced.

18

19 -0x20000: disable audio splicing flag

20

21 This bit when set, disables all of the audio processing around the splicing points except
22 for the PTS and PCR re-computation. All of the audio present in the clip is played in this
23 case.

1 With reference to FIG. 50, there is shown a diagram that illustrates a metered file
2 transfer protocol (FTP). This protocol is useful for transfer of an MPEG TS stream from
3 the video file server (20 in FIG. 1) to an application 310. The application 310, for
4 example, is a client application on the network 25, or it could be another video file server.
5 The application 310 initiates the metered FTP by sending a copy command to the active
6 one of the controller servers 28, 29. The controller server sends a set bandwidth
7 command to the stream server to set the bit rate for the metered transfer of file data
8 between the stream server 291 and the application 310. The stream server then issues a
9 connect message to the application to open an IP channel for the transfer of the file data.
10 In the metered FTP protocol, the data transmission rate is controlled so that the loading
11 on the stream server is deterministic. The data transmission is TCP flow controlled. For
12 input to the stream server from the application, the stream server controls the data rate by
13 flow-control push-back. For transmission of data from the stream server to the
14 application, the stream server merely controls the rate at which it transmits the data.

15 In the transmission control protocol (TCP), the stream server either opens or
16 closes a window of time within which to receive more data. The stream server indicates
17 to the application a certain number of buffers that are available to receive the data. In
18 addition, the stream sever acknowledges receipt of the data.

19 In the metered FTP protocol, time is split up into one-second intervals, and at
20 every 1/10 of a second, the average data rate is re-computed. An adjustment is made to a
21 data transmission interval parameter if the computed data rate deviates from the desired
22 rate. For example, for a desired 10 kilobyte per second transmission rate, the data
23 transmission size is set at one kilobyte, and the data transmission interval parameter is

1 initially set at 1/10 of a second. If the computed average data rate happens to be less than
2 10 kilobytes per second, then a one kilobyte bunch of data will be transmitted more
3 frequently than once every 1/10 of a second.

4 With reference to FIG. 51, there is shown a control station play list 320 and a
5 stream server play list 321. As described in the above referenced Duso et al. U.S. Patent
6 5,892,915, the stream server can continuously supply a real-time data stream to a client
7 by servicing a play list. As shown in FIG. 51, the play list can be distributed between the
8 controller server play list 320 and a stream server play list 321. The controller server
9 play list, for example, holds up to 356 elements that point to clips, and the stream server
10 play list holds up to three of the elements. The stream server play list is in effect a
11 window to up to three of the elements that are at or near the head of the controller server
12 play list. When a pointer to a clip is placed in a play-list entry, the entry also has an
13 indication of an In Point in the clip, an Out Point for the clip, and a desired start time. A
14 pointer to a clip can be recalled (i.e., removed) from a play-list entry.

15 When a pointer to a clip is appended to the controller server play list 320, extra
16 audio packets are loaded in a FIFO buffer. Then, the start and the end positions of the
17 clip are set based on the video elementary stream only. The clip is read starting with the
18 first video frame to play and until the end of the last frame to play. One dedicated buffer
19 is associated with each audio stream. The number of additional audio access units to play
20 is computed at the splicing time. All of these pre-fetched audio access units will be
21 played only if the clip is played until the end. However, if the play-out of the clip is
22 interrupted by a "play-next immediate" or a "play-next at-time" command then some of

1 the preloaded extra audio is replaced by audio data (i.e. audio access units) extracted
2 from the new clip's buffer pool at the splicing time.

3 The seamless splicing techniques described above can also be used to recover
4 from failure conditions that may destroy or corrupt a portion of an MPEG transport
5 stream. For example, a component of a data path in the cached disk array may fail,
6 causing an MPEG TS from a disk drive in the cached disk array to be interrupted for a
7 short period of time while the failure condition is diagnosed and the MPEG TS is re-
8 routed to bypass the failed component. As shown in the flow chart of FIG. 52, the MPEG
9 processing module may be programmed to recognize the failure (step 351) during the
10 delivery of the MPEG TS to a client (step 352). Once this failure is detected, the MPEG
11 processing module 303 can fill in this gap in the MPEG TS with null packets or freeze
12 frames with correct PCR values (step 353). By inserting correct PCR values at less than
13 the required minimum interval (less than 100 milliseconds), a client's decoder will not
14 reset and can be kept in a ready state. Once delivery of the MPEG TS to the MPEG
15 processing module is reestablished (as detected in step 354), the MPEG processing
16 module seamlessly splices (step 355) the re-established TS (as if it were a second stream
17 or clip) to the TS of null packets or freeze frames that it has been generating and sending
18 to the client. Splicing could be performed in a similar fashion in the set-top decoder box
19 of FIG. 2 or the switch of FIG. 3 to compensate for temporary interruptions in the
20 delivery of an MPEG TS to the set-top decoder box or to the switch.

21 In a similar fashion, the MPEG processing module in batch mode could check a
22 clip for any damaged portions, and once a damaged portion is found, remove it by
23 seamlessly splicing the end of the first good part of the clip to the beginning of the last

1 good part of the clip. Batch mode processing also would have the advantage that the
2 audio and video buffer levels could be determined exactly by simulation, so that it would
3 be possible to guarantee the absence of any buffer underflow or overflow at every point
4 after the splice. Batch mode processing, with audio and video buffer simulators, could
5 also measure the quality of spliced TS streams and determine whether or not the splices
6 should be repaired using the more accurate simulated buffer levels. The quality
7 measurement could also include an analysis of audio delay or skew; how many freeze
8 frames are in the TS stream and their clustering, and an analysis of PCR jitter. It would
9 also be very easy for the MPEG processing module to compute the audio skew and PCR
10 jitter in real time during the real-time transmission of an MPEG TS, and to display
11 continuous traces of the audio skew and PCR jitter to a system administrator.

12 In view of the above, there has been described the preparation of metadata for
13 splicing of an encoded digital motion video stream (such as an MPEG Transport Stream)
14 is prepared in real time while recording at the encoding bit rate and faster than encoded
15 bit rate for off line encoding independent of the bit rate and mechanisms for ingestion of
16 the data stream into data storage. Preprocessing is performed during a metered file
17 transfer protocol (FTP) and includes pseudo real-time encoding. The preprocessing
18 includes Group of Pictures (GOP) level pre-processing of splicing In Points and results in
19 an intimate linkage between metadata and the file system in which the video data is
20 stored. The preferred file system enables access to metadata in parallel to writing the
21 data on disk. The pre-processing is performed simultaneous to writing the data to the
22 disk using a carousel type buffer mechanism.

1 What is claimed is:

2
3 1. A method of preparing metadata for splicing of a transport stream including
4 video access units encoding video presentation units representing video frames, the video
5 access units of the transport stream encoding the video presentation units using a data
6 compression technique and containing a variable amount of compressed video data, the
7 method including:

8 a) a server ingesting the transport stream;
9 b) the server storing the transport stream in a file in data storage;
10 c) concurrently with storing the transport stream in the file in data storage, the
11 server computing metadata for splicing of the transport stream, and storing the metadata
12 for splicing in the file.

13
14 2. The method as claimed in claim 1, wherein the transport stream is MPEG-2
15 compliant.

16
17 3. The method as claimed in claim 1, wherein the ingestion of the transport
18 stream, the computation of the metadata, and the storage of the transport stream and the
19 metadata in the file occurs at least as fast as real time.

20
21 4. The method as claimed in claim 1, wherein the data is ingested in the server
22 and the metadata are computed during a metered file transfer protocol (FTP).

23

1 5. The method as claimed in claim 1, which includes storing the ingested
2 transport stream in a carousel of buffers, accessing the carousel of buffers to compute the
3 metadata and to store the metadata in the carousel of buffers, and then accessing the
4 carousel of buffers to transfer data of the transport stream and corresponding metadata to
5 the file in data storage.

6
7 6. The method as claimed in claim 5, wherein the server includes a stream
8 server computer and a cached disk storage subsystem, the carousel of buffers are
9 allocated in random access memory of the stream server computer, and the stream server
10 computer is programmed with a file system that maps the file to disk storage in the
11 cached disk storage subsystem and that writes the data of the transport stream and
12 corresponding metadata to the file in disk storage of the cached disk storage subsystem.

13
14 7. The method as claimed in claim 5, wherein the server includes a network
15 interface board that ingests the transport stream and loads the transport stream into the
16 carousel of buffers using a direct memory access protocol.

17
18 8. The method as claimed in claim 1, wherein the computing of the metadata
19 for the splicing of the transport stream includes computing an extrapolated program
20 counter value (PCR_e) for a respective first I-frame in each of a plurality groups of
21 pictures (GOPs) in the transport stream.

22

1 9. The method as claimed in claim 8, wherein the computing of the metadata
2 for splicing includes computing a decode time stamp (DTS) corresponding to the
3 extrapolated program counter value (PCR_e) for the respective first I-frame in each of a
4 plurality of groups of pictures (GOPs) in the transport stream.

5
6 10. The method as claimed in claim 9, wherein the respective DTS and PCR_e
7 values for the GOPs are stored in a GOP index in a header of the file.

8
9 11. The method as claimed in claim 10, wherein the GOP index further
10 includes at least one frame number and a pointer to the transport stream data in the file
11 for each of said plurality of groups of pictures (GOPs) in the transport stream.

12
13 12. The method as claimed in claim 10, wherein the metadata includes values
14 for attributes of each of a plurality of groups of pictures (GOPs) in the transport stream,
15 and the values are stored in a GOP index in the file.

16
17 13. The method as claimed in claim 12, wherein the GOP index includes an
18 entry for each of the plurality of GOPs, and each entry includes at least one frame
19 number of a frame in the respective GOP, a pointer to where transport stream data of the
20 respective GOP is stored in the file, and values for other attributes of the respective GOP.

21

1 14. The method as claimed in claim 13, wherein the GOP index is in the form
2 of a table and is stored in a header of the file after metadata about the transport stream as
3 a whole.

4
5 15. The method as claimed in claim 1, which includes decimating the GOP
6 index by reducing the number of entries in the GOP index to make room for entries of
7 additional GOPs in the transport stream being ingested.

8
9 16. The method as claimed in claim 1, which includes skipping metadata
10 computations for a group of pictures (GOP) in the transport stream when there are
11 insufficient computational resources available for computing the metadata for the group
12 of pictures (GOP) concurrently with ingestion of the transport stream.

13
14 17. The method as claimed in claim 1, wherein the metadata includes values
15 of attributes of groups of pictures (GOPs) in the transport stream, the attributes include
16 high priority attributes and low priority attributes, and the method includes computing
17 values for both high priority attributes and low priority attributes when there are
18 sufficient computational resources available for computing values for both the high
19 priority attributes and the low priority attributes concurrently with ingestion of the
20 transport stream into the server, and the method includes computing the values for the
21 high priority attributes but not the low priority attributes when there are sufficient
22 computational resources available for computing values for the high priority attributes

1 but not the low priority attributes concurrently with ingestion of the transport stream into
2 the server.

3
4 18. A data storage device containing a file of data of a transport stream including
5 video access units encoding video presentation units representing video frames, the video
6 access units of the transport stream encoding the video presentation units using a data
7 compression technique and containing a variable amount of compressed video data,
8 wherein the file also contains an index to groups of pictures (GOPs) in the transport
9 stream, and the index to the groups of pictures includes pointers to transport stream file
10 data of respective ones of the GOPs, and the file further contains attributes of the GOPs
11 computed from the data of the transport stream, and the attributes of the GOPs are also
12 indexed by the index to the groups of pictures.

13
14 19. The data storage device as claimed in claim 20, wherein the index to the
15 groups of pictures is in the form of a table of entries for the respective ones of the GOPs.

16
17 20. The data storage device as claimed in claim 19, wherein each entry
18 includes at least one frame number of a frame in the respective GOP, a pointer to where
19 transport stream data of the respective GOP is stored in the file, and values for other
20 attributes of the respective GOP.

1 21. The data storage device as claimed in claim 18, wherein the index to the
2 groups of pictures is stored in a header of the file after metadata about the transport
3 stream as a whole.

4
5 22. The data storage device as claimed in claim 18 wherein the computed
6 attributes for each respective GOP includes an extrapolated program counter value
7 (PCR_e) for a respective first I-frame in the respective GOP.

8
9 23. The data storage device as claimed in claim 22, wherein the computed
10 attributes for each respective GOP includes a decode time stamp (DTS) corresponding to
11 the extrapolated program counter value (PCR_e).

12
13 24. The data storage device as claimed in claim 18, wherein the transport
14 stream is MPEG-2 compliant.

15
16 25. A method of real-time seamless splicing of a first transport stream to a
17 second transport stream to produce a spliced transport stream, the first transport stream
18 including video access units encoding video presentation units representing video frames,
19 the video access units of the first transport stream encoding the video presentation units
20 using a data compression technique and containing a variable amount of compressed
21 video data, the second transport stream including video access units encoding video
22 presentation units representing video frames, the video access units of the second
23 transport stream encoding the video presentation units using a data compression

1 technique and containing a variable amount of compressed video data, the first transport
2 stream having a last video frame to be included in the spliced transport stream, and the
3 second transport stream having a first video frame to be included in the spliced transport
4 stream, each of the video access units having a time at which each video access unit is to
5 be received in a video decoder buffer and a time at which said each video access unit is to
6 be removed from the video decoder buffer, said method comprising:

7 (a) setting the time at which the video access unit for the first video frame of the
8 second transport stream is to be removed from the video decoder buffer to a time
9 following in a decoding sequence next after the time at which the last video access unit
10 for the last frame of the first transport stream is to be removed from the video decoder
11 buffer;

12 (b) accessing pre-computed metadata for the second transport stream including
13 metadata about a decode time stamp (DTS_{F2}) at which the beginning of the video access
14 unit for the first video frame of the second transport stream is removed from the video
15 decoder buffer and an extrapolated program clock reference (PCR_{e2}) time at which the
16 beginning of the video access unit for the first video frame of the second transport stream
17 will be received in the video decoder buffer, and using the pre-computed metadata to
18 adjust content of the first transport stream so that the beginning of the video access unit
19 for first video frame of the second transport stream will be received in the video decoder
20 buffer immediately after the end of the video access unit for the last video frame of the
21 first transport stream is received in the video decoder while maintaining the difference
22 ($DTS_{F2} - PCR_{e2}$) in the spliced transport stream; and

1 (c) concatenating a portion of the first transport stream up to and including the last
2 video frame to a portion of the second transport stream including and subsequent to the
3 first video frame.

4
5 26. The method as claimed in claim 25, wherein the content of the first
6 transport stream is adjusted by replacing at least one video access unit in the first
7 transport stream with a video access unit encoding a freeze frame having a size selected
8 so that the beginning of the video access unit for the first video frame of the second
9 transport stream will be received in the video decoder buffer immediately after the end of
10 the video access unit of the last video frame of the first transport stream is received in the
11 video decoder buffer.

12
13 27. The method as claimed in claim 26, which includes selecting the size of
14 the freeze frame by selecting the size of at least one slice in the freeze frame.

15
16 28. The method as claimed in claim 25, wherein the second transport stream
17 has a higher bit transmission rate than the first transport stream.

18
19 29. The method as claimed in claim 25, wherein the second transport stream
20 has a lower bit transmission rate than the first transport stream.

21
22 30. The method as claimed in claim 25, wherein the first transport stream, the
23 second transport stream, and the spliced transport stream are MPEG-2 compliant.

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31. The method as claimed in claim 25, which includes parsing the first transport stream and the second transport streams in real time for audio PES packet headers, parsing the audio PES packets in real time for audio access units (AAUs), identifying in real time non-obsolete AAUs in the first transport stream following the last video frame in the first transport stream and identifying in real time obsolete AAUs in the second transport stream following the first video frame in the second transport stream, reformatting the non-obsolete AAUs in the first transport stream following the last video frame in the first transport stream in real time, eliminating the obsolete AAUs in the second transport stream following the first video frame in the second transport stream in real time, and computing time stamp offsets in real time and re-stamping, in real time, time stamps and continuity counters in the spliced transport stream following the first video frame from the second transport stream.

32. The method as claimed in claim 25, wherein the real-time seamless splicing is performed by a server when reading the first transport stream and the second transport stream from file storage and streaming the spliced transport stream to an application.

33. The method as claimed in claim 32, wherein the server streams the spliced transport stream to the application using a metered file transfer protocol (FTP).

34. The method as claimed in claim 32, which includes the server reading data of the first transport stream and the second transport stream from file storage and storing the data of the first transport stream and the second transport stream in a carousel of buffers, accessing the carousel of buffers to splice the first transport stream to the second transport stream and store data of the spliced transport stream in the carousel of buffers, and then accessing the carousel of buffers to transfer data of the spliced transport stream from the carousel of buffers for streaming to the application.

35. The method as claimed in claim 34, wherein the data of the first transport stream are stored in a first series of alternate buffers in sequence around the carousel, and data of the second transport stream are stored in a second series of alternate buffers in sequence around the carousel.

36. The method as claimed in claim 34, wherein the server includes a stream server computer and a cached disk storage subsystem, the carousel of buffers are allocated in random access memory of the stream server computer, and the stream server computer is programmed with a file system that maps the file storage to disk storage in the cached disk storage subsystem and that reads the data of the first transport stream and the second transport stream from disk storage of the cached disk storage subsystem for storing of the data of the first transport stream and the second transport stream in the carousel of buffers.

1 37. The method as claimed in claim 34, wherein the server includes a network
2 interface board that reads the data of the spliced transport stream from the carousel of
3 buffers for streaming to the application using a direct memory access protocol.
4

5 38. The method as claimed in claim 37, wherein the network interface board
6 communicates with the application using a technology selected from group consisting of
7 DVB, ATM, Ethernet, Fiber Channel, and Gigabit Ethernet.
8

ABSTRACT

Metadata for splicing of an encoded digital motion video stream (such as an MPEG Transport Stream) is prepared in real time while recording at the encoding bit rate and faster than encoded bit rate for off line encoding independent of the bit rate and mechanisms for ingestion of the data stream into data storage. Preprocessing is performed during a metered file transfer protocol (FTP) and includes pseudo real-time encoding. The preprocessing includes Group of Pictures (GOP) level pre-processing of splicing In Points and results in an intimate linkage between metadata and the file system in which the video data is stored. The preferred file system enables access to metadata in parallel to writing the data on disk. The pre-processing is performed simultaneous to writing the data to the disk using a carousel type buffer mechanism.

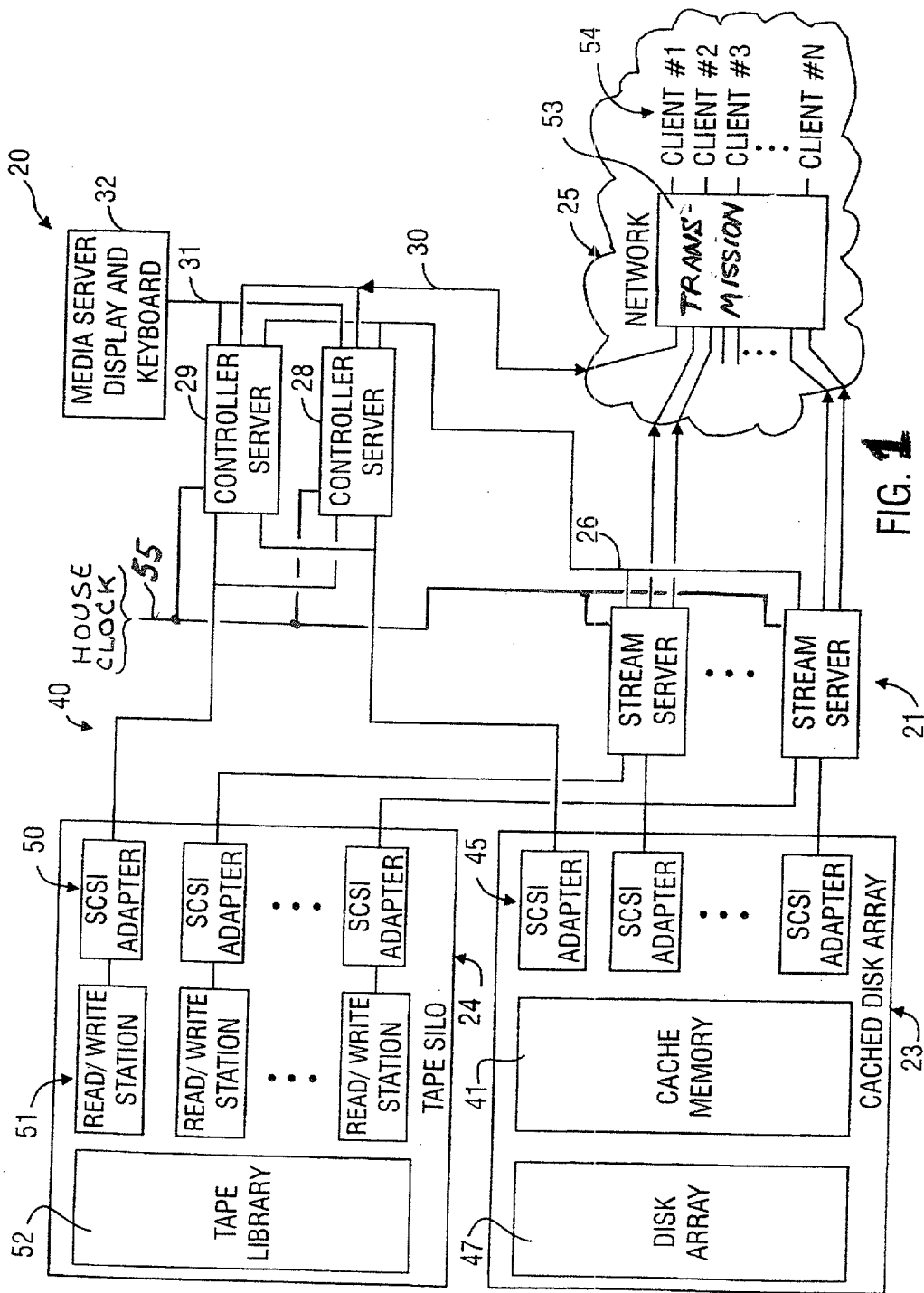


FIG. 1

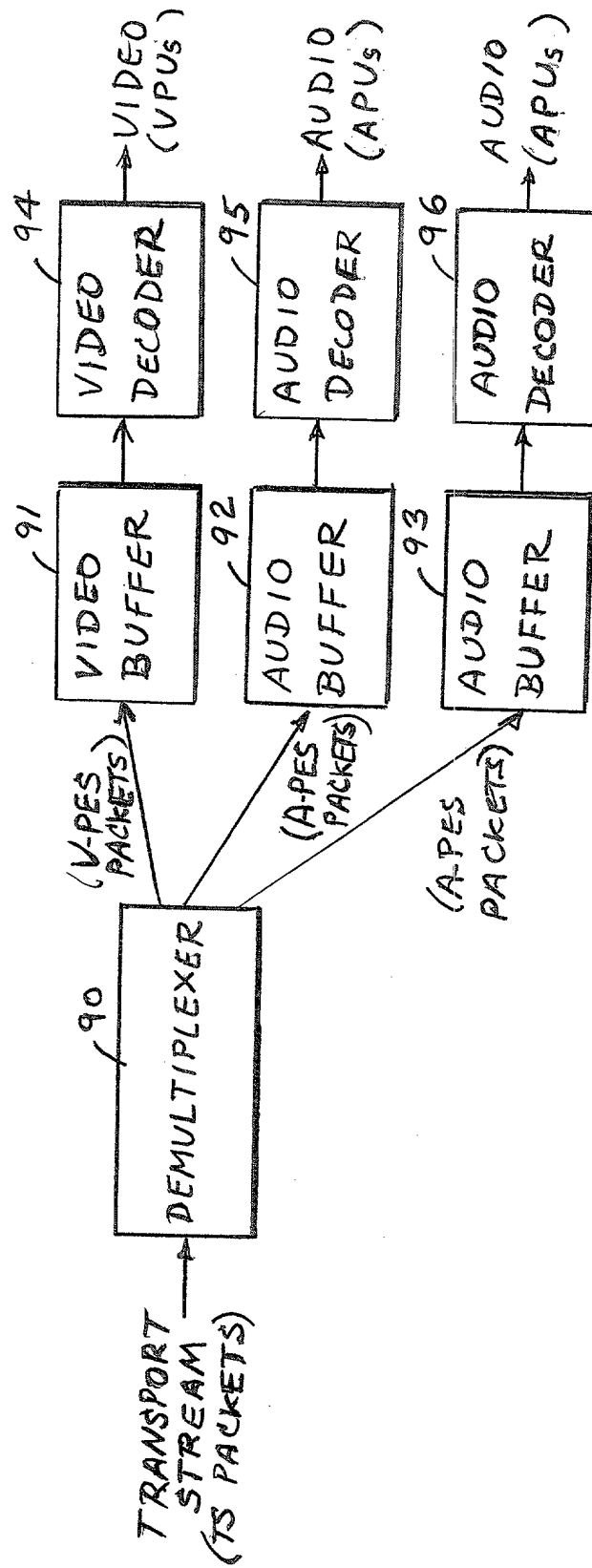


FIG. 4

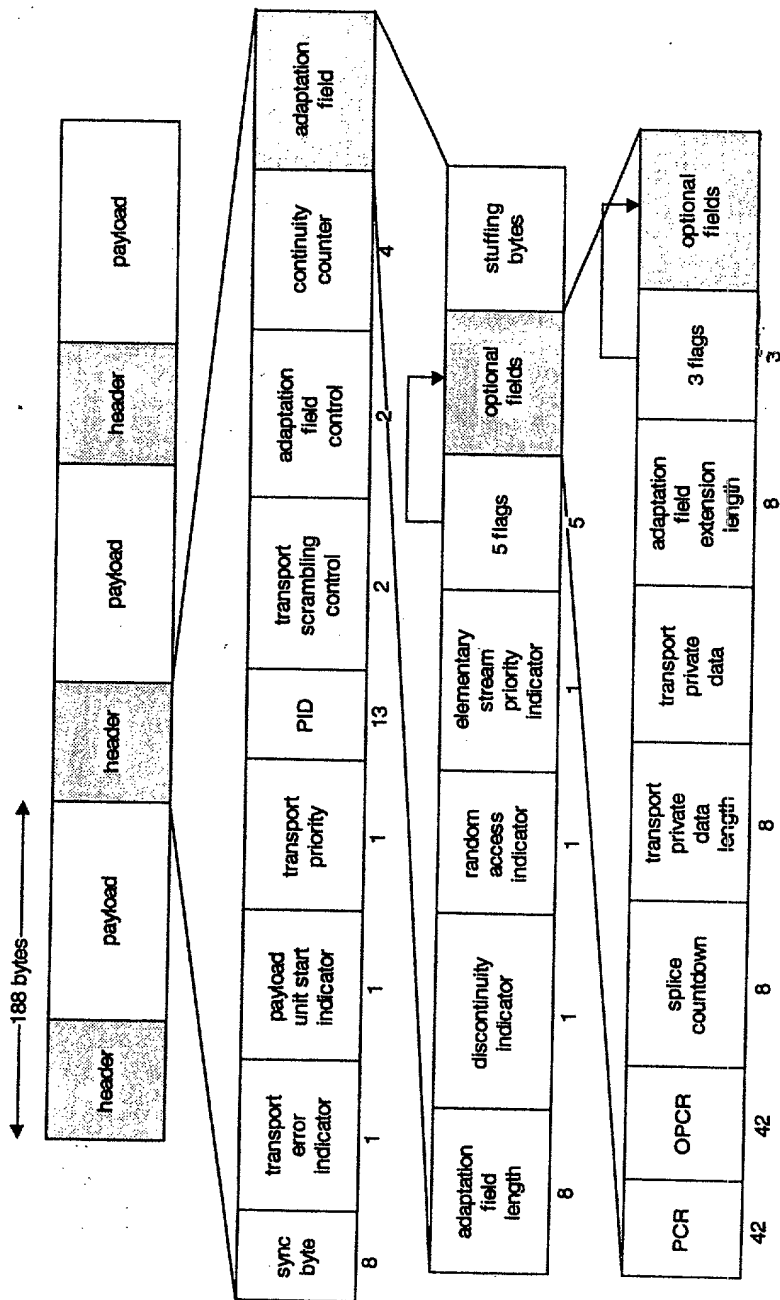


FIG. 5

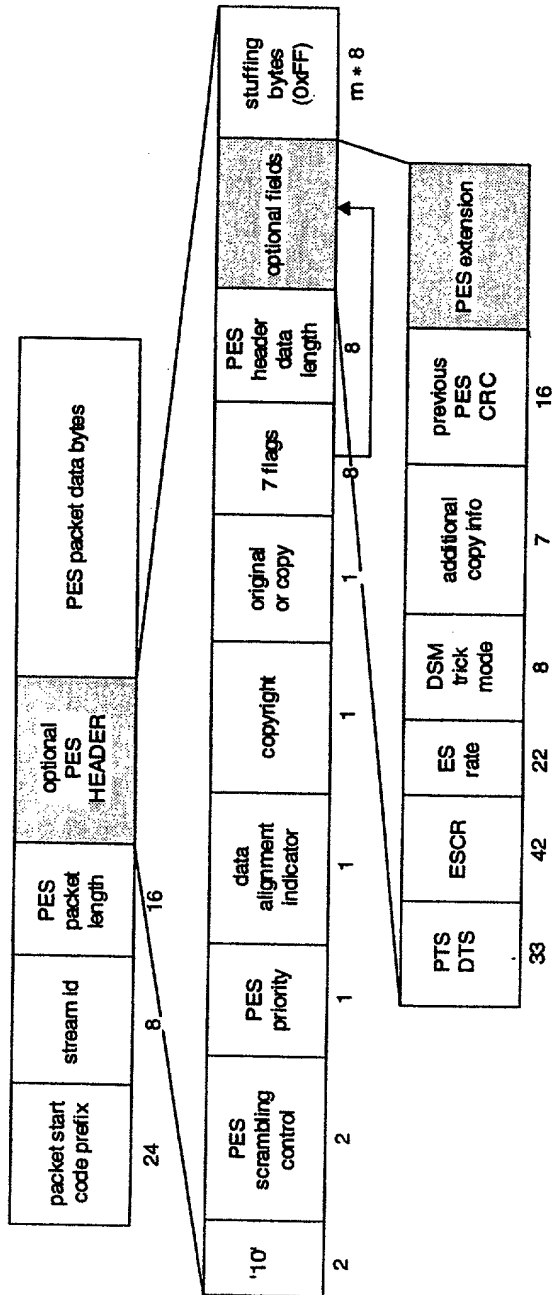
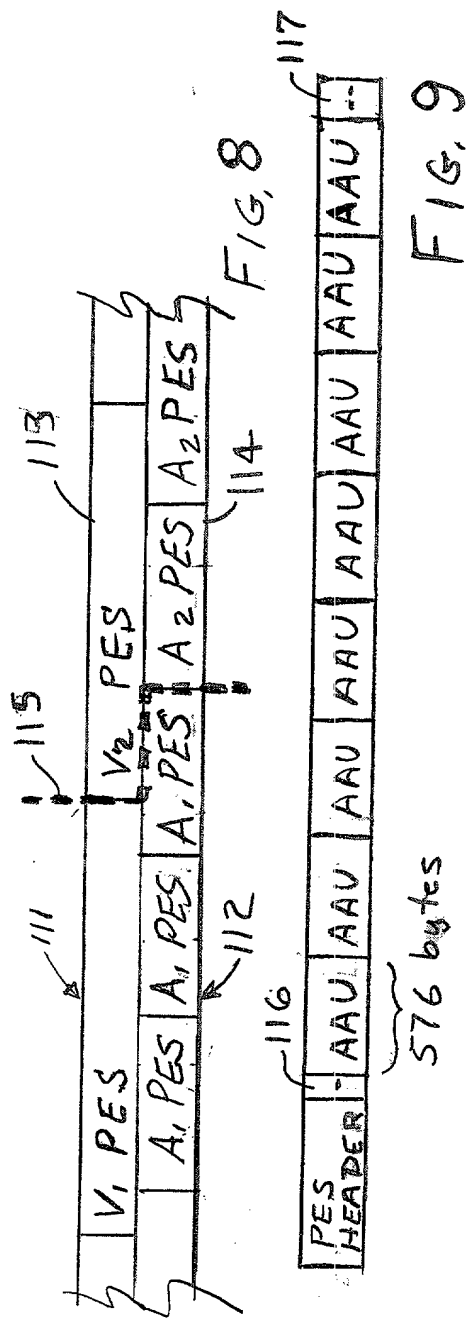
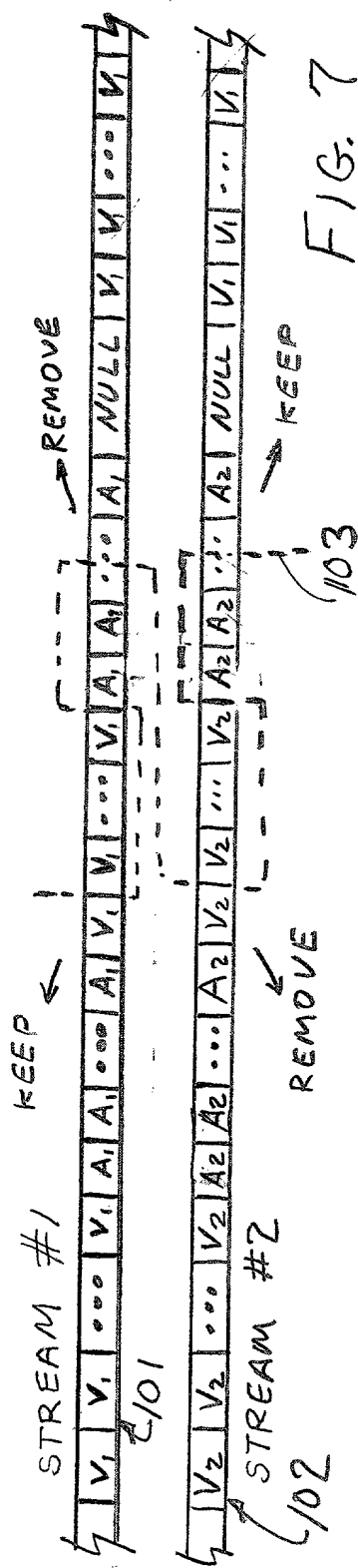
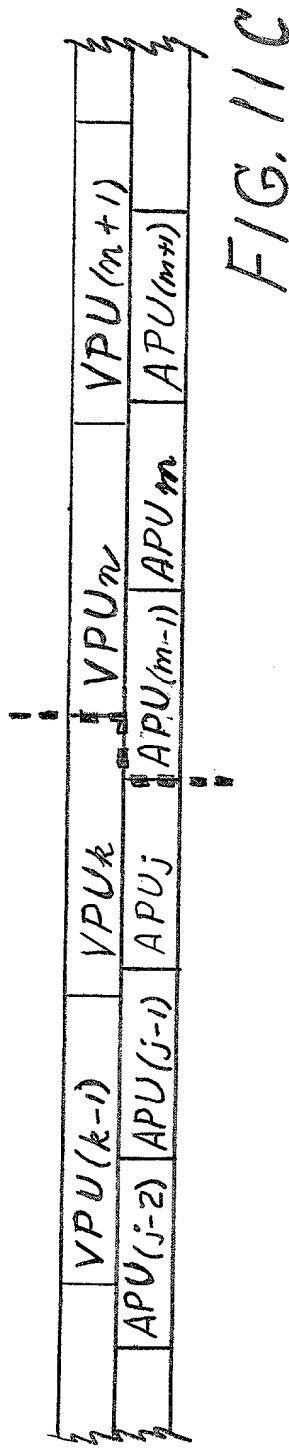
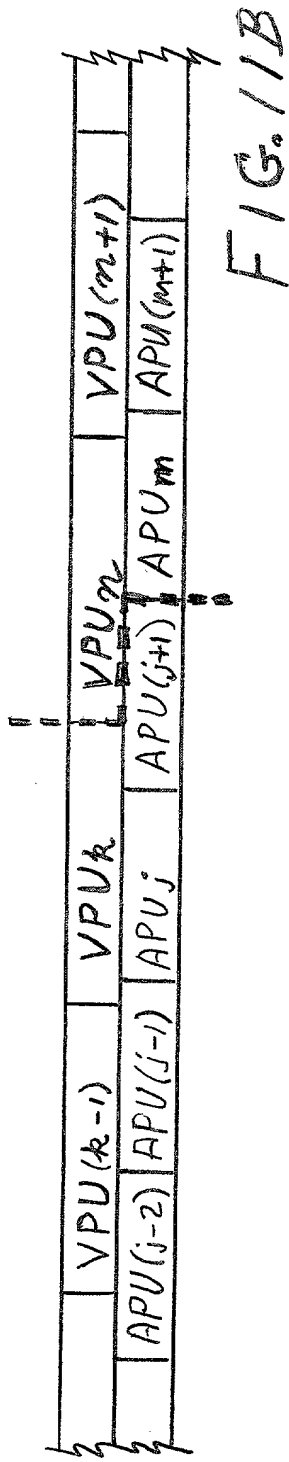
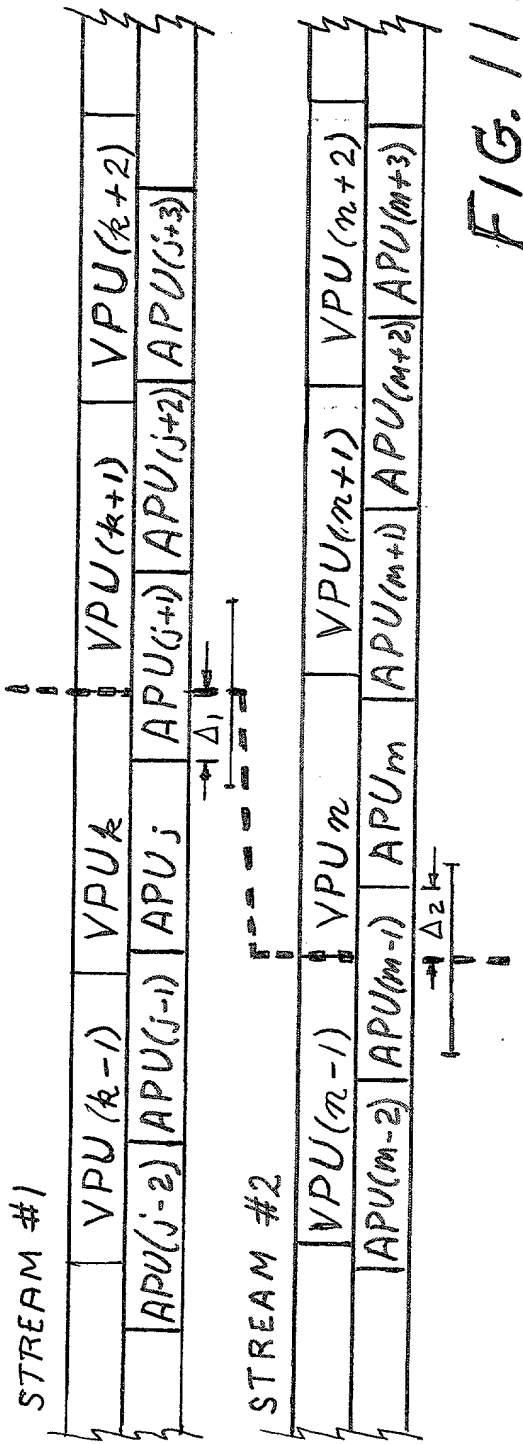


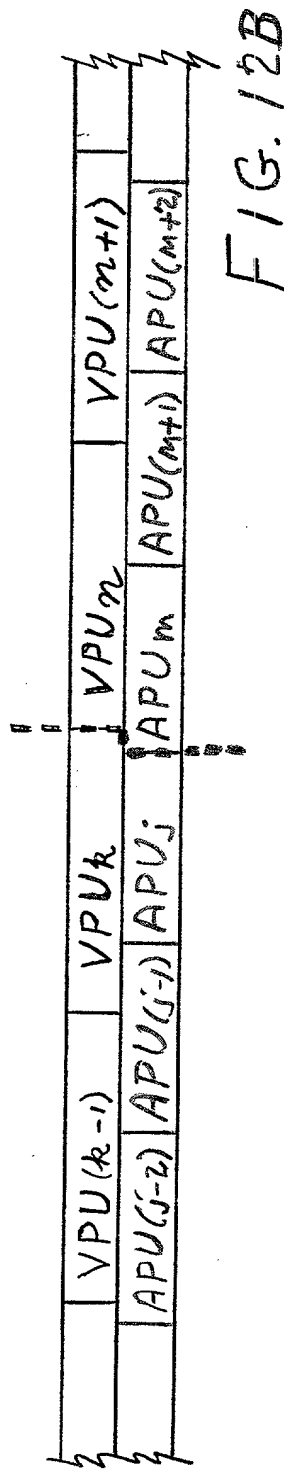
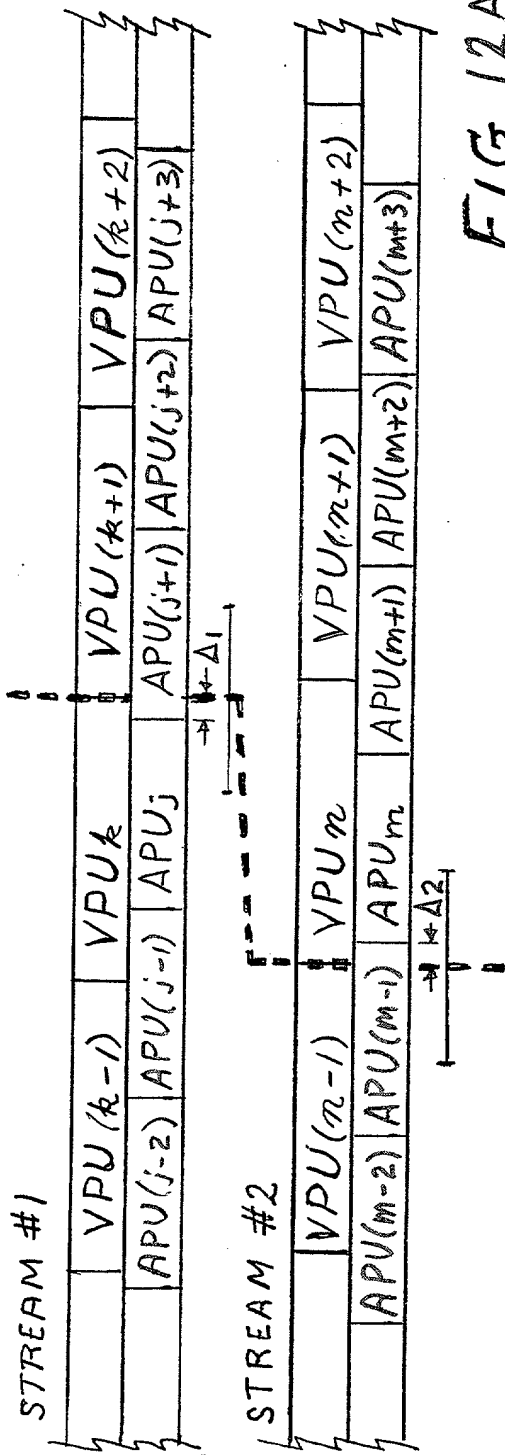
FIG. 6

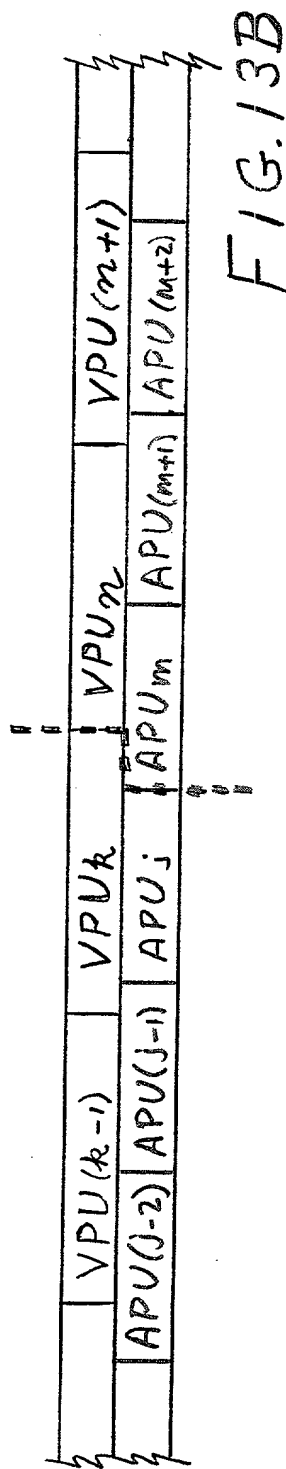
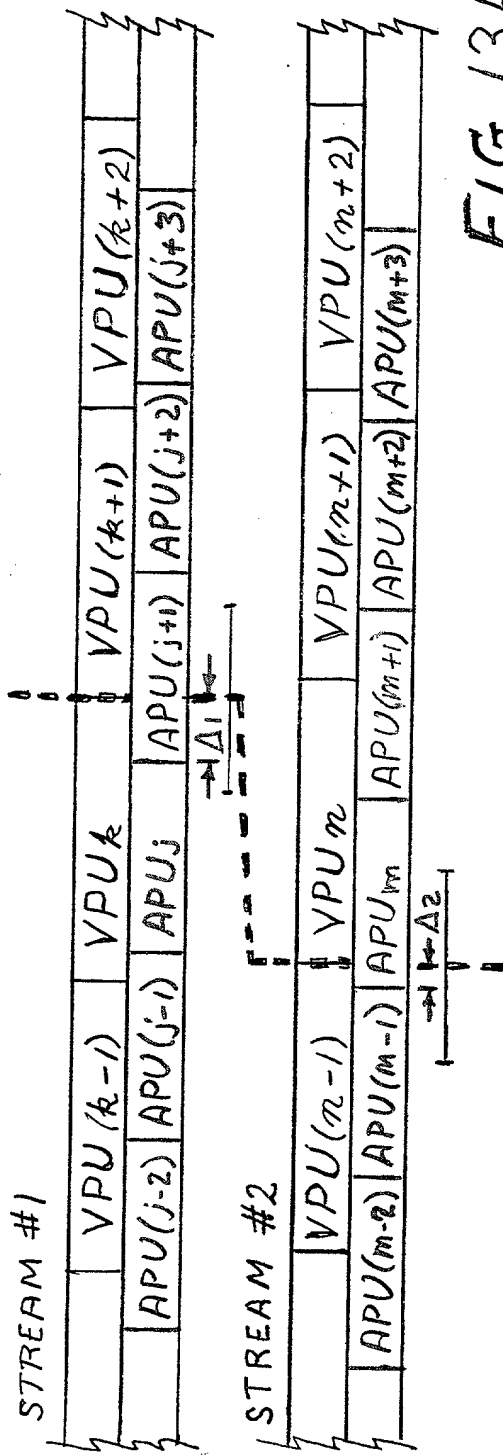


STREAM #1 BEST ALIGNED APU <u>SHORT</u> INTO THE CUT ($\Delta_1 > 0$)	STREAM #2 BEST ALIGNED APU <u>SHORT</u> INTO THE CUT ($\Delta_2 < 0$)	12 msec. < audio gap < 24 msec. ($\Delta_1 - \Delta_2$)	FIGS. 11A, 11B, 11C
		0 msec. < audio gap < 12 msec. ($\Delta_1 - \Delta_2$)	FIGS. 12A, 12B
	STREAM #2 BEST ALIGNED APU <u>LONG</u> INTO THE CUT ($\Delta_2 > 0$)	0 msec. < audio gap < 12 msec. ($\Delta_1 - \Delta_2$)	FIGS. 13A, 13B
		0 msec. < audio overlap < 12 msec. ($\Delta_2 - \Delta_1$)	FIGS. 14A, 14B
STREAM #1 BEST ALIGNED APU <u>LONG</u> INTO THE CUT ($\Delta_1 < 0$)	STREAM #2 BEST ALIGNED APU <u>SHORT</u> INTO THE CUT ($\Delta_2 < 0$)	0 msec. < audio gap < 12 msec. ($\Delta_1 - \Delta_2$)	FIGS. 15A, 15B
		0 msec. < audio overlap < 12 msec. ($\Delta_2 - \Delta_1$)	FIGS. 16A, 16B
	STREAM #2 BEST ALIGNED APU <u>LONG</u> INTO THE CUT ($\Delta_2 > 0$)	12 msec. < audio overlap < 24 msec. ($\Delta_2 - \Delta_1$)	FIGS. 17A, 17B, 17C
		0 msec. < audio overlap < 12 msec. ($\Delta_2 - \Delta_1$)	FIGS. 18A, 18B

FIG. 10







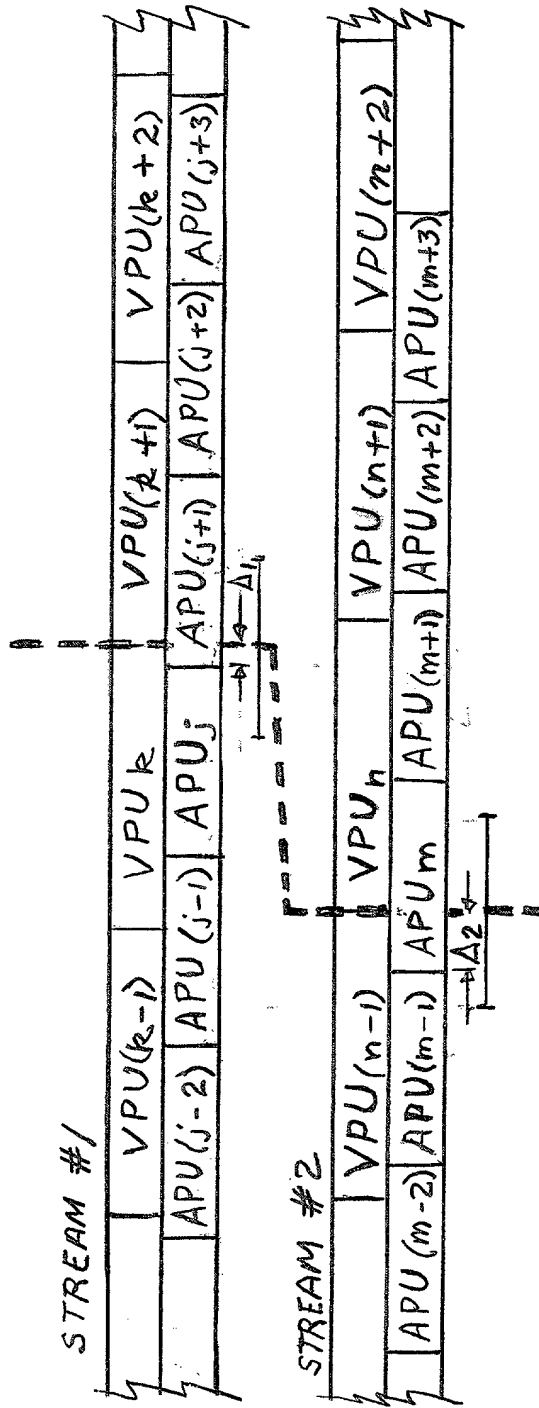


FIG. 14A

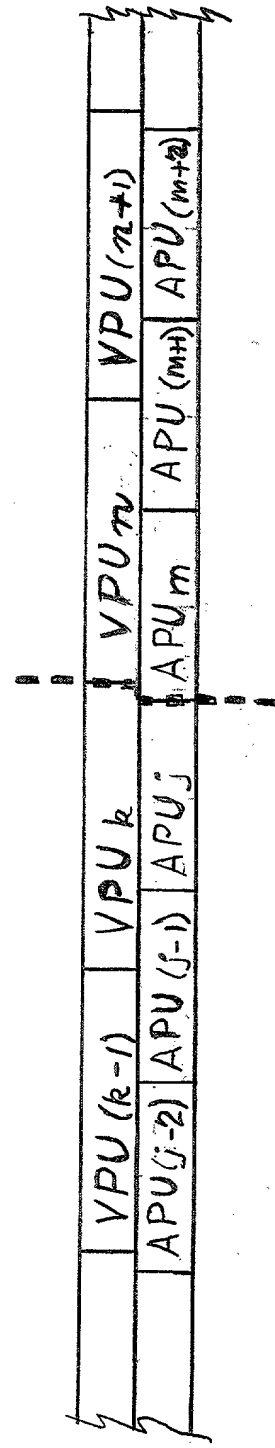


FIG. 14B

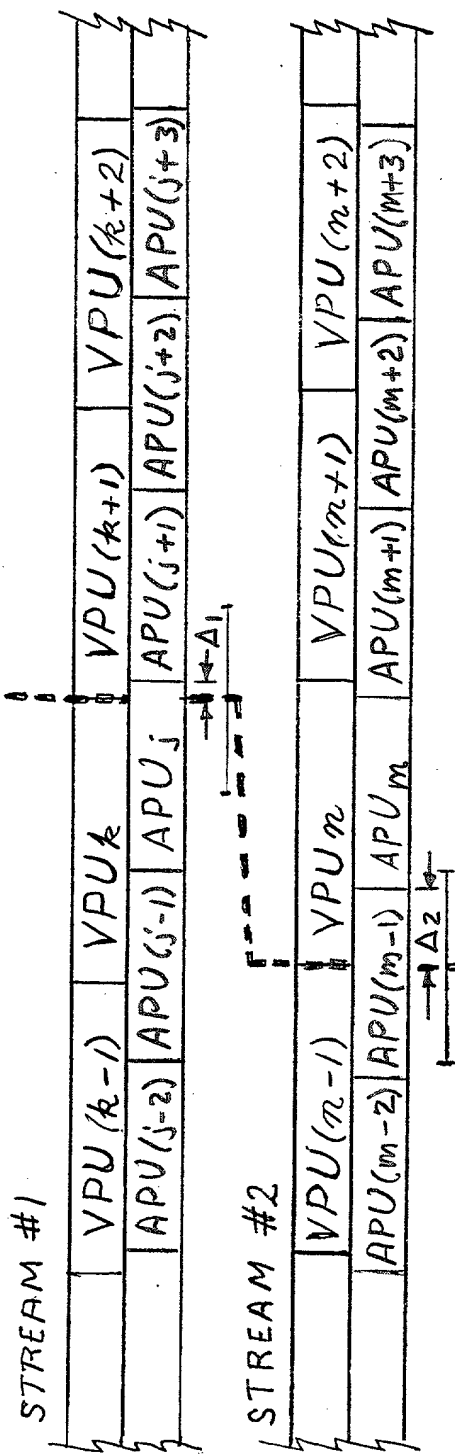


FIG. 15A

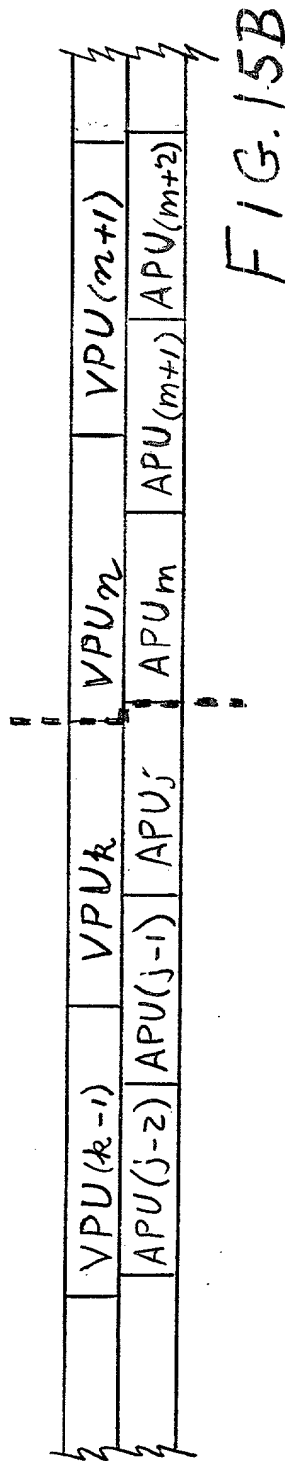


FIG. 15B

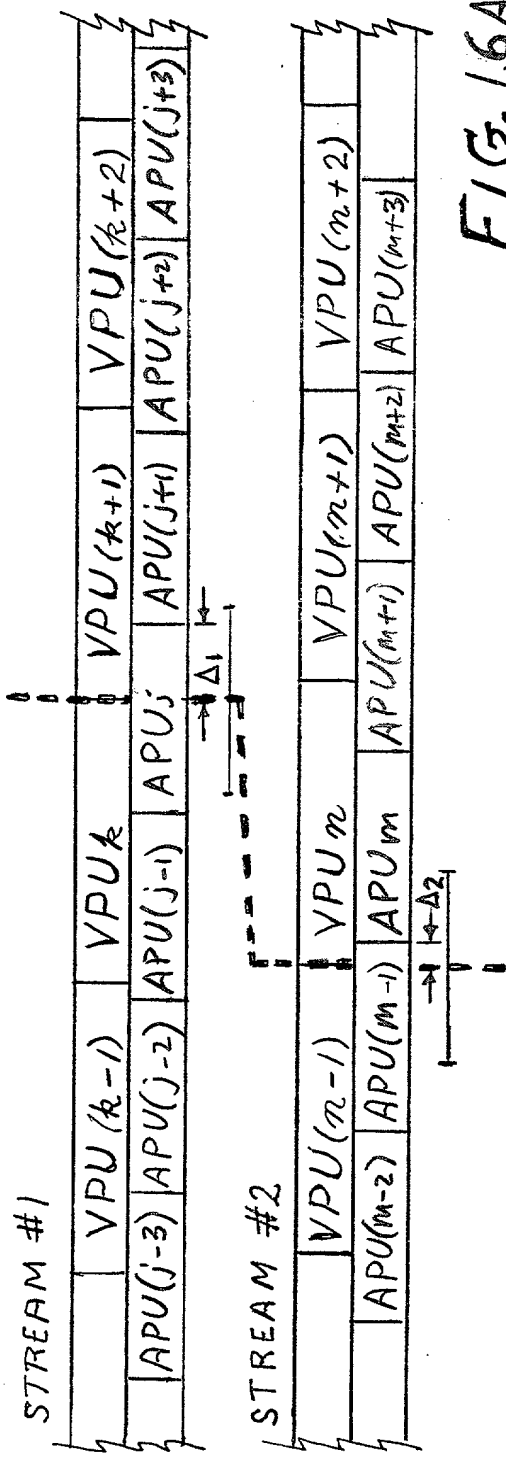


FIG. 16A

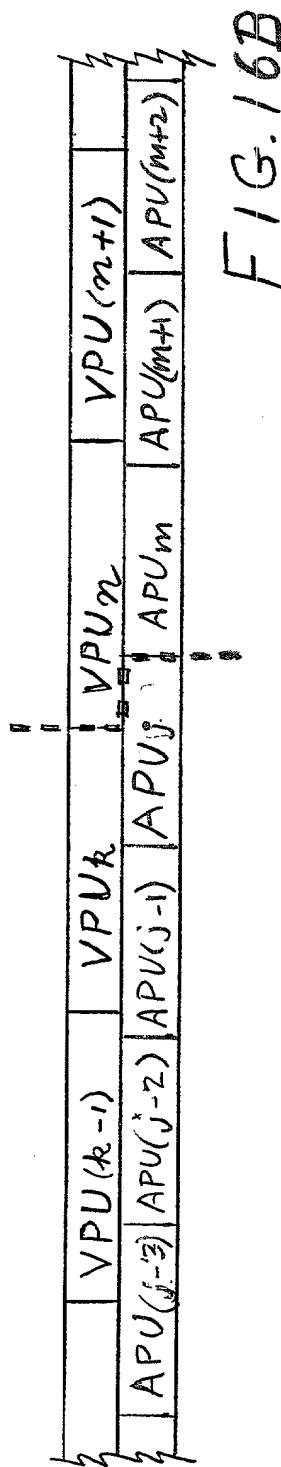


FIG. 16B

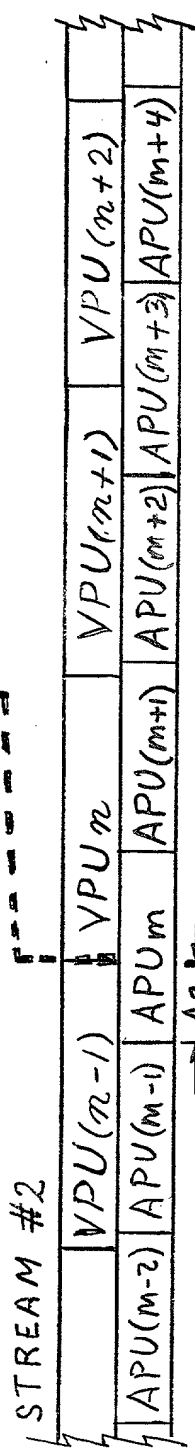
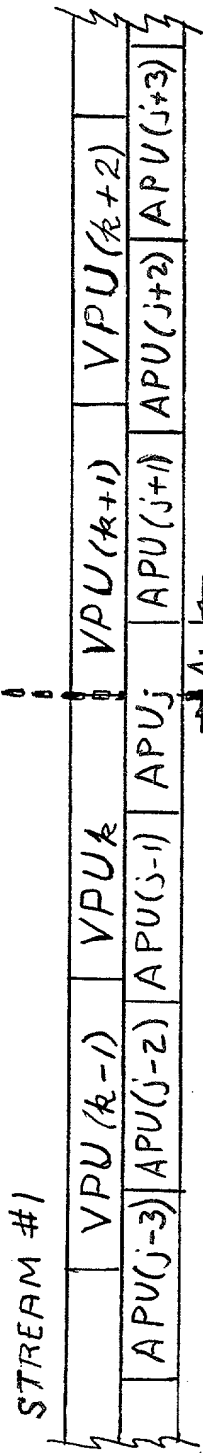


FIG. 17A

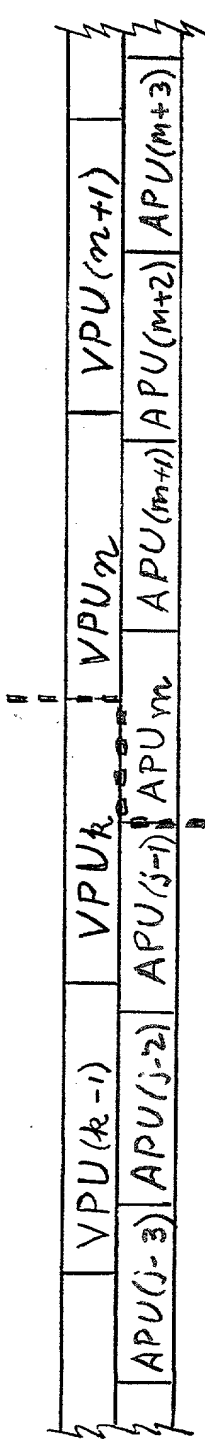
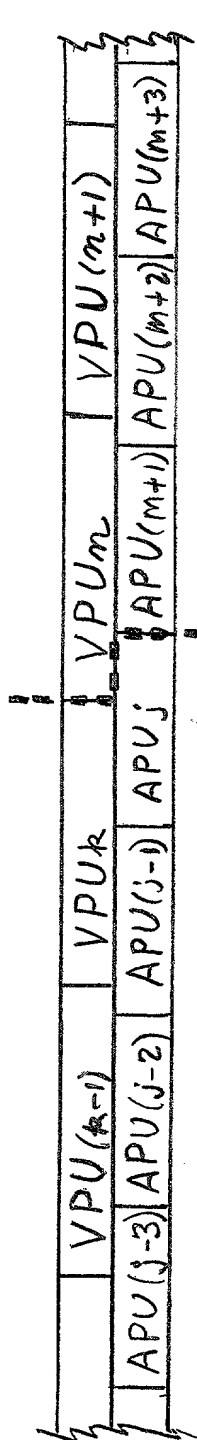


FIG. 17C



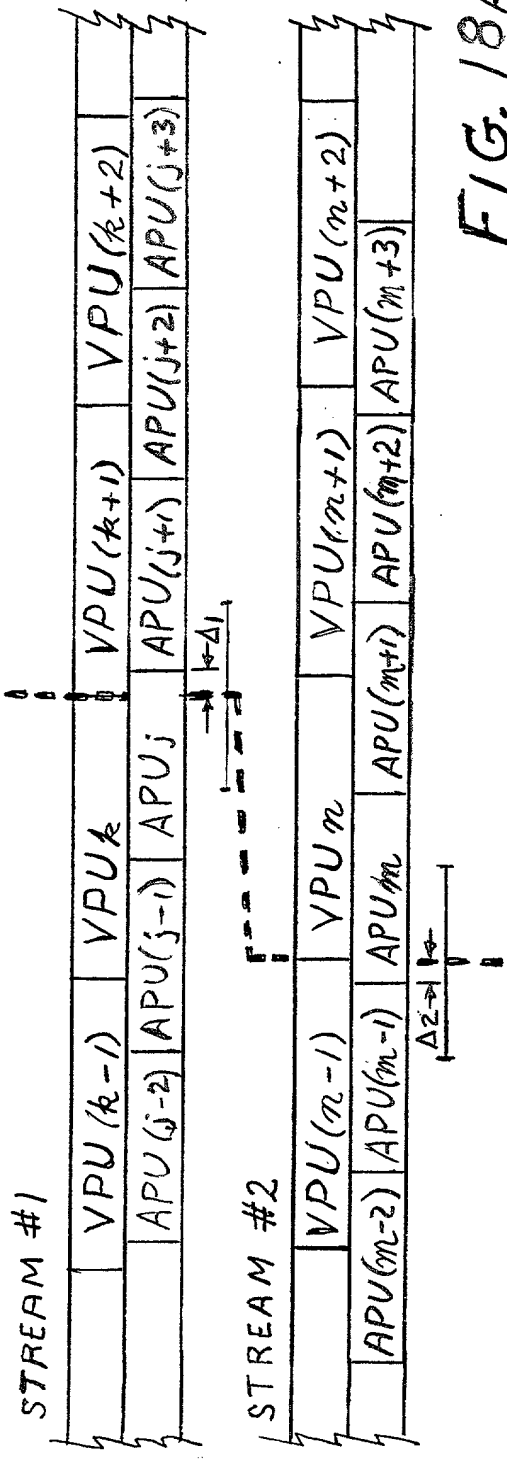


FIG. 18A

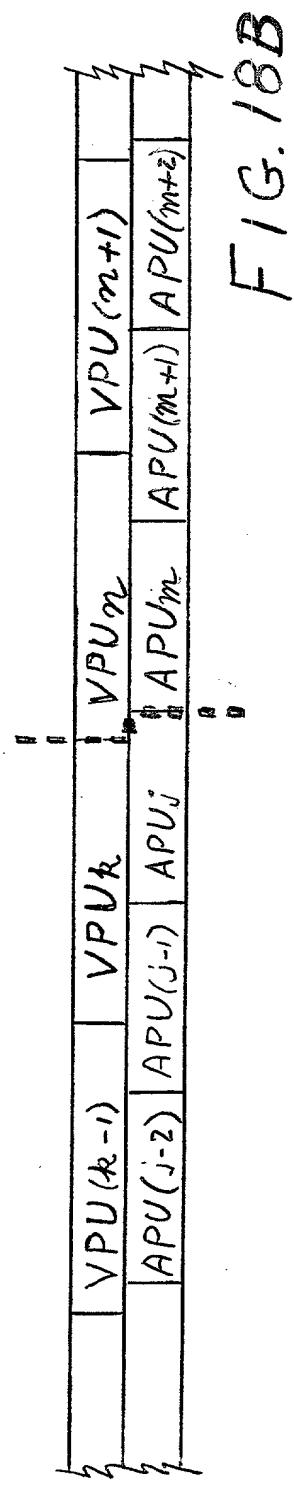


FIG. 18B

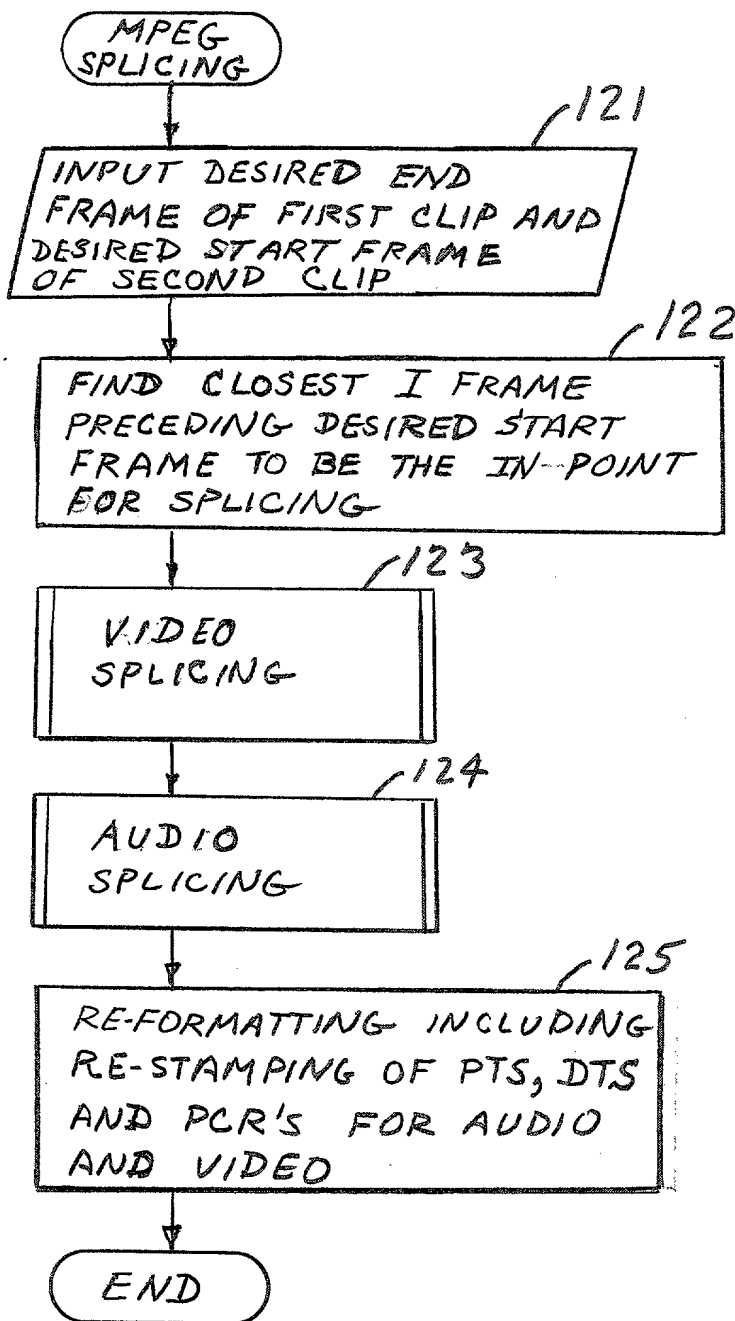
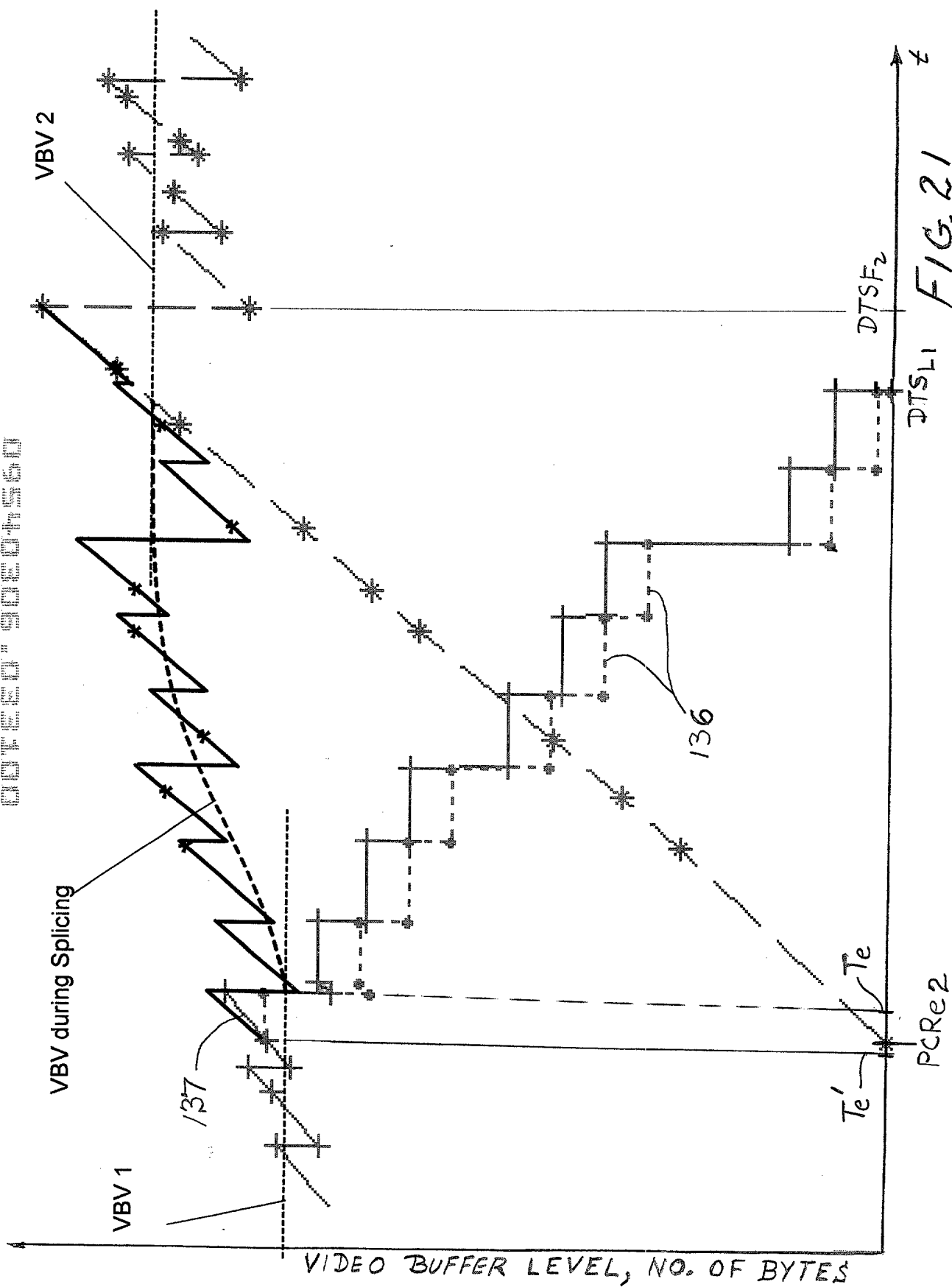


FIG. 19



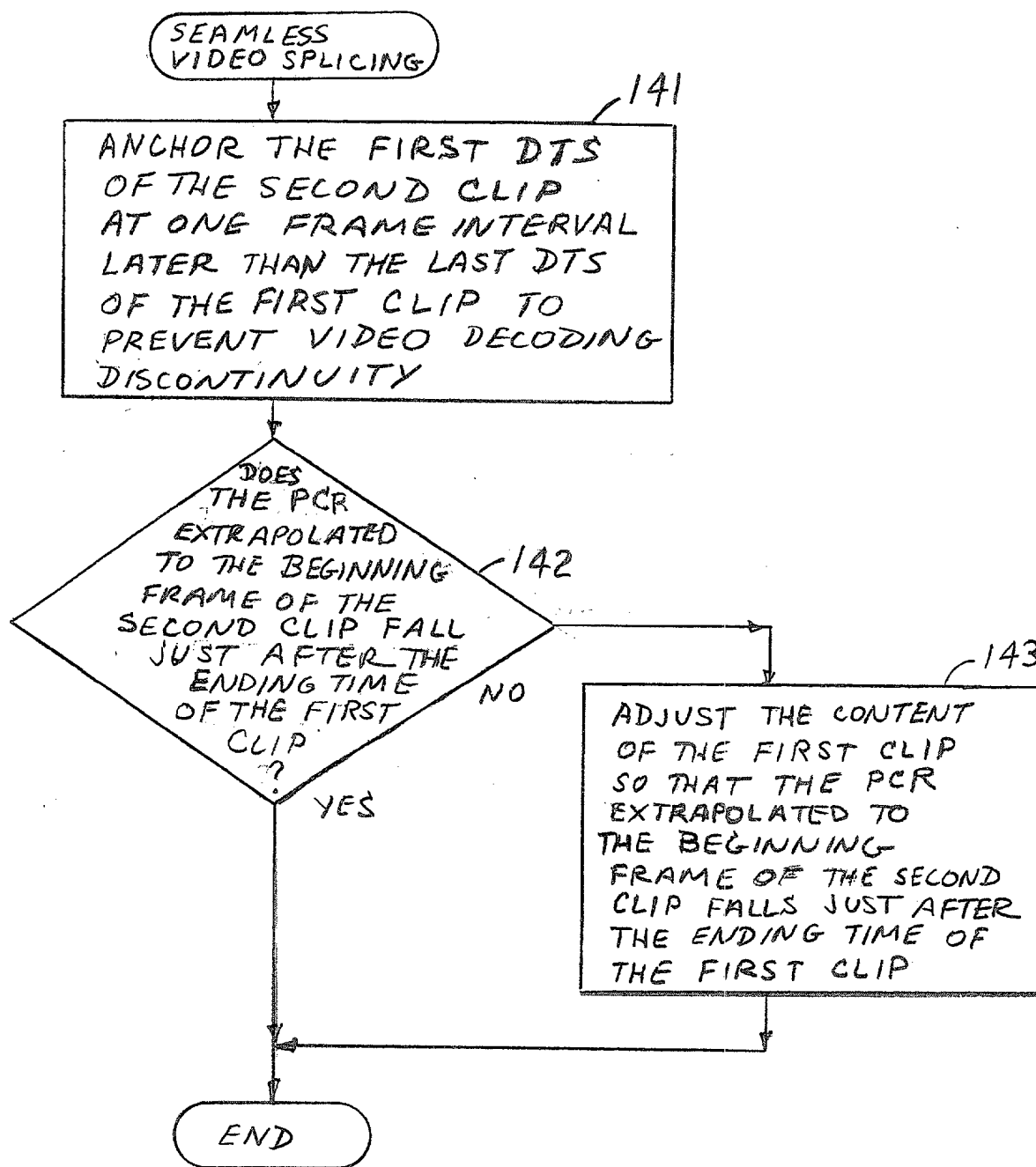


FIG. 22

VIDEO
SPLICING

151
DETERMINE THE LAST DTS/PTS
OF THE FIRST CLIP
(DTS_{L1})

152
DETERMINE THE TIME OF
ARRIVAL (T_e) OF THE LAST
BYTE OF THE FIRST CLIP

153
ADD ONE FRAME INTERVAL
TO DTS_{L1} TO FIND THE
DESIRED FIRST DTS LOCATION
FOR THE SECOND CLIP
($DTS_{F1} = DTS_{L1} + 1/FR$)

154
KEEPING THE $DTS-PCR_e$
RELATION UNALTERED FOR
THE SECOND CLIP, FIND THE
TIME INSTANT T_s AT WHICH
THE FIRST BYTE OF THE
SECOND CLIP SHOULD
ARRIVE

$$(T_{START} = DTS_{F2} - PCR_{e2})$$

$$(T_s = DTS_{F1} - T_{START})$$

B

FIG. 23

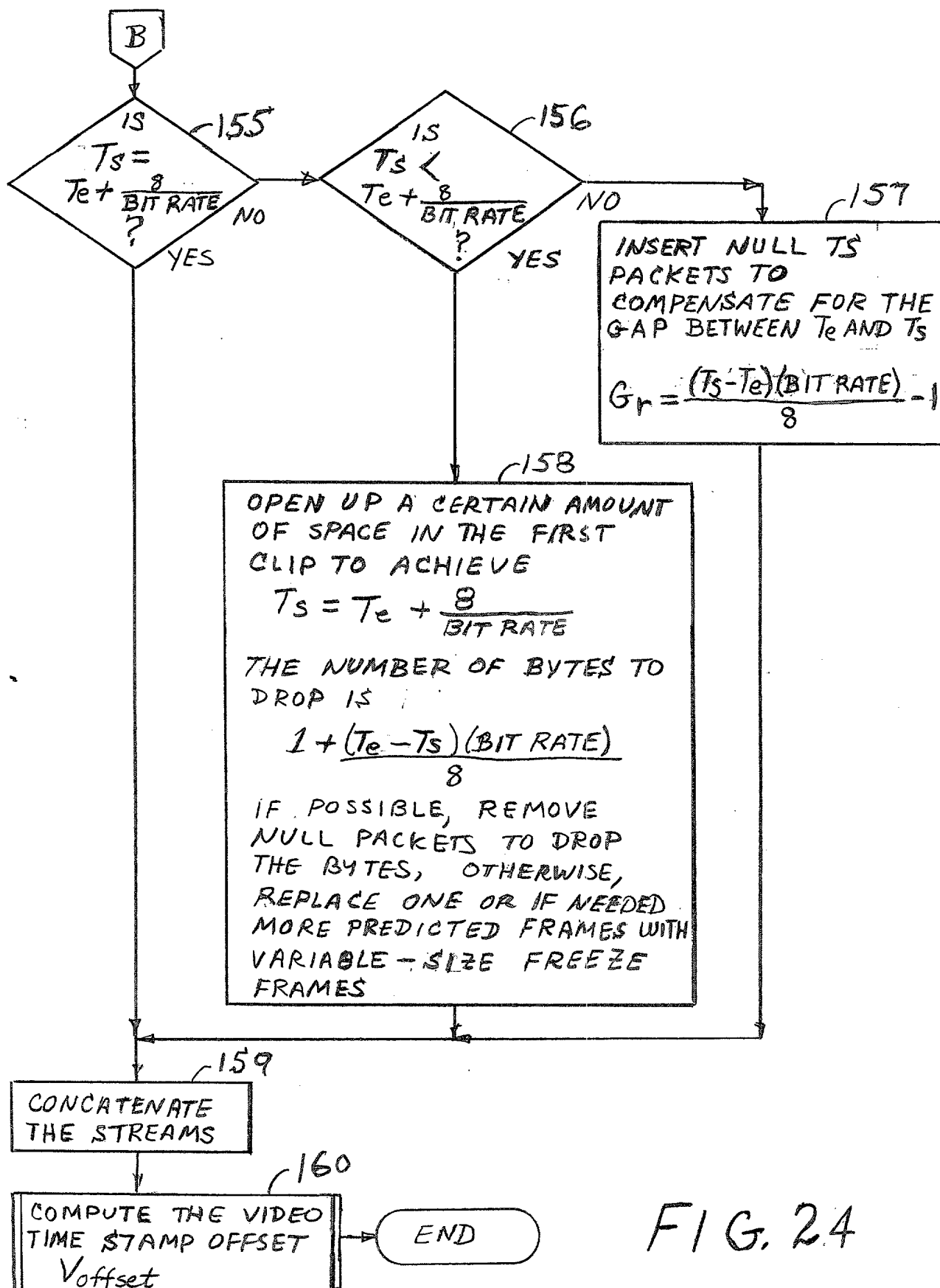


FIG. 24

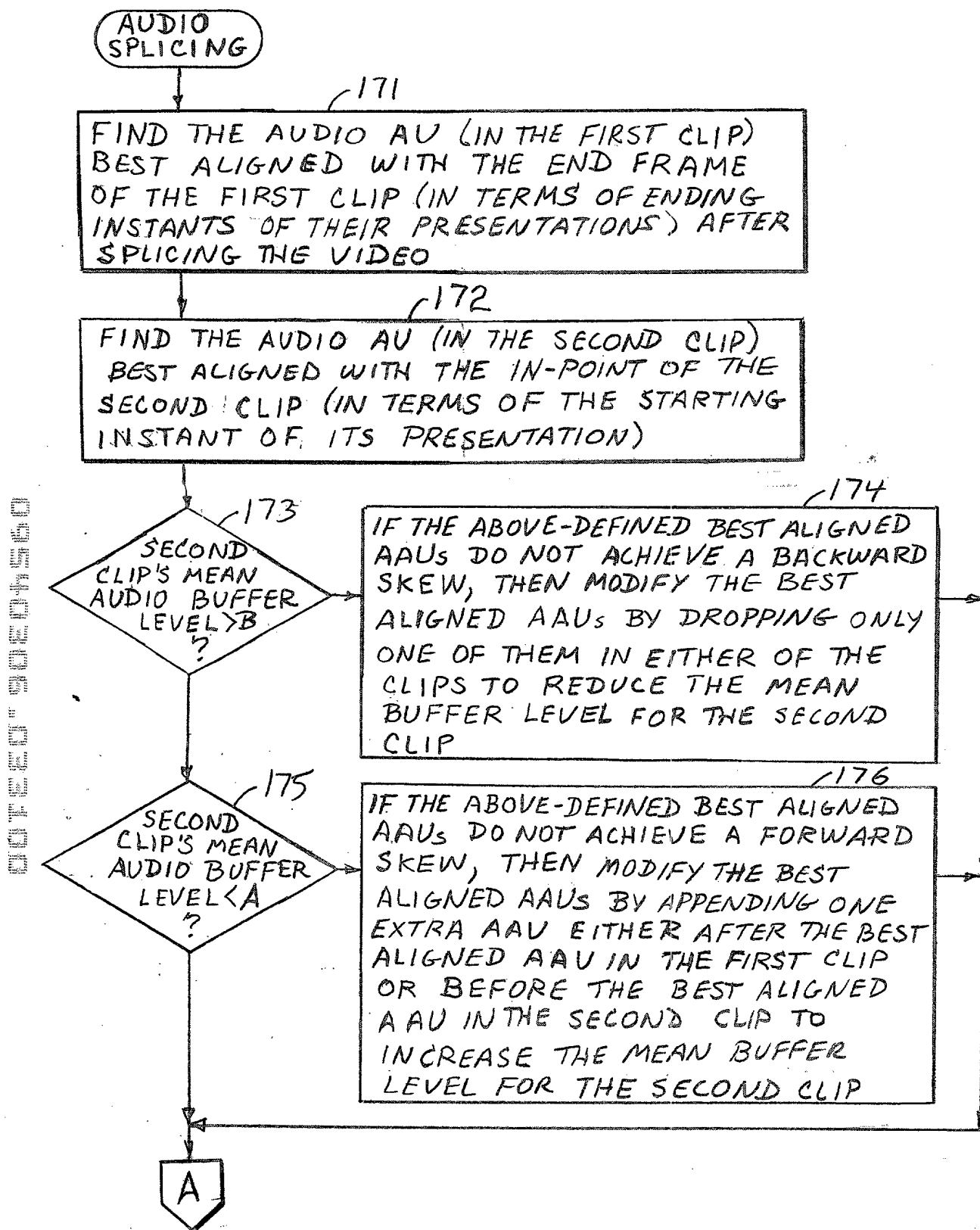


FIG. 25

A

177
REMOVE ALL AUs OF AUDIO IN THE FIRST CLIP AFTER THE BEST ALIGNED AAU IN THE FIRST CLIP, AND ADJUST THE LAST AUDIO PES PACKET HEADER IN THE FIRST CLIP TO REFLECT THE CHANGE IN ITS SIZE IN BYTES AFTER THE REMOVAL

178
FIND THE AUDIO PES PACKET IN THE SECOND CLIP WHICH INCLUDES THE BEST ALIGNED AAU IN THE SECOND CLIP, AND REMOVE ALL AAUs PRECEDING THE BEST ALIGNED ONE IN THIS PES PACKET

179
PRODUCE A PES PACKET HEADER TO ENCAPSULATE THE BEST ALIGNED AAU AND THE AAUs AFTER IT, AND WRITE THE PES PACKET SIZE INTO THE HEADER

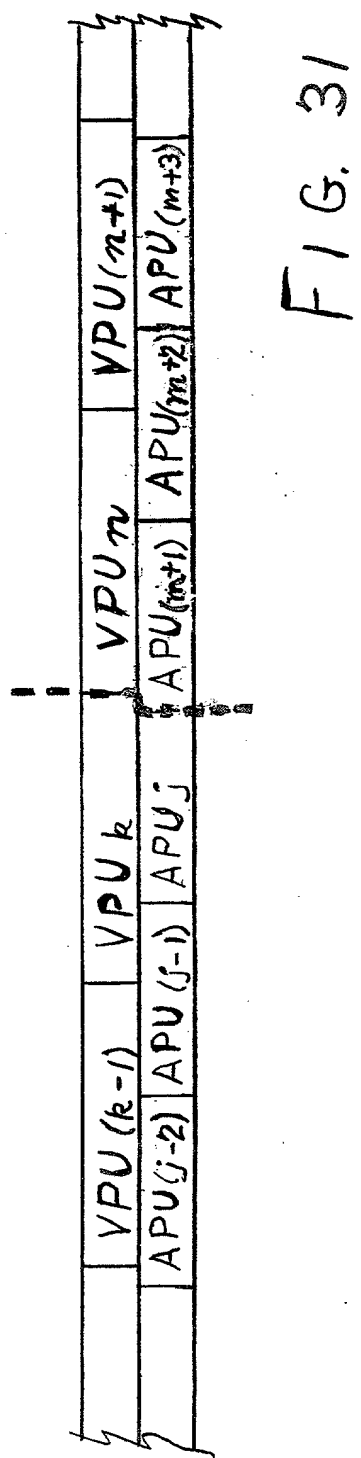
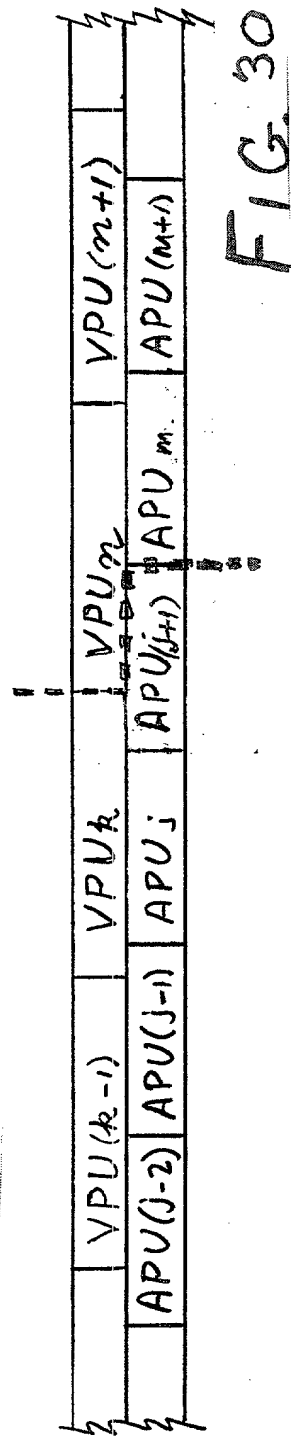
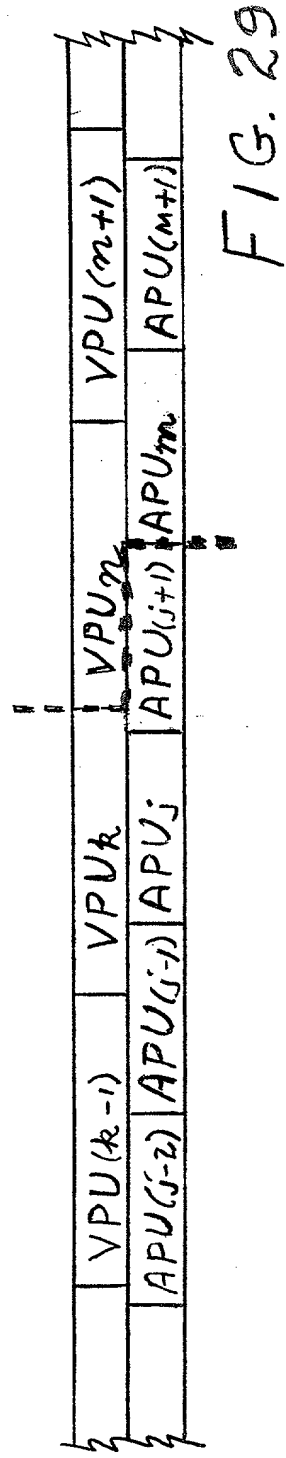
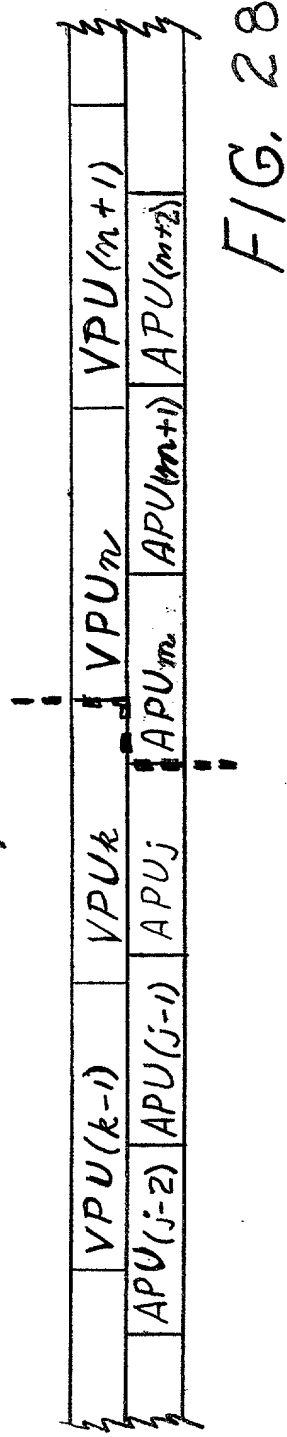
180
CALCULATE THE REQUIRED AUDIO PTS OFFSET TO BE USED FOR RESTAMPING THE AUDIO OF THE SECOND CLIP

END

FIG 26

CASE	SECOND CLIP HAS A HIGH MEAN AUDIO BUFFER LEVEL	SECOND CLIP HAS A LOW MEAN AUDIO BUFFER LEVEL
FIG. 11A	USE FIG. 28	USE FIG. 11B OR 11C
FIG. 12A	USE FIG. 12B	USE FIG. 29
FIG. 13A	USE FIG. 13B	USE FIG. 30
FIG. 14A	USE FIG. 31	USE FIG. 14B
FIG. 15A	USE FIG. 15B	USE FIG. 32
FIG. 16A	USE FIG. 33	USE FIG. 16B
FIG. 17A	USE FIG. 17B OR 17C	USE FIG. 34
FIG. 18A	USE FIG. 35	USE FIG. 18B

FIG. 27



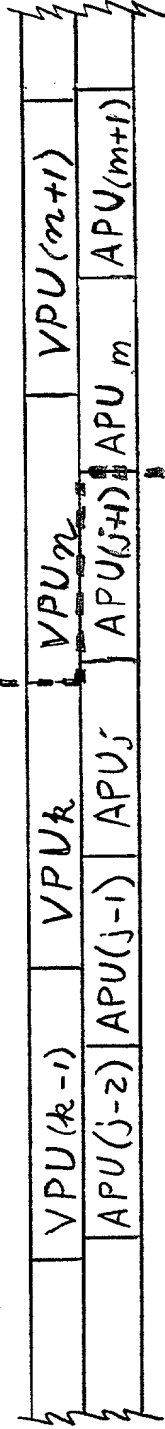


FIG. 32

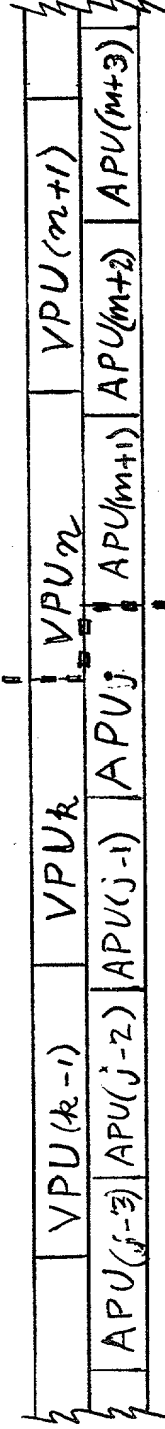


FIG. 33

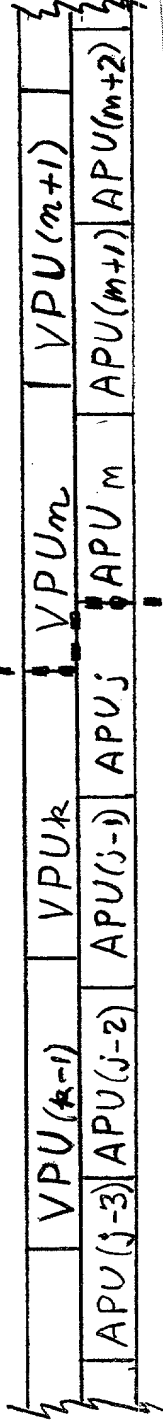


FIG. 34

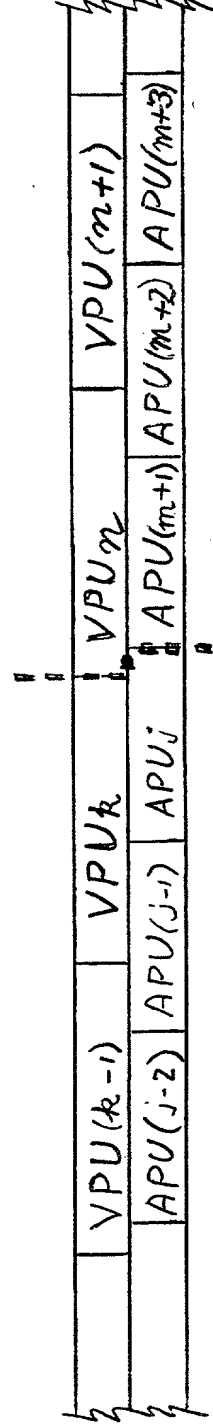


FIG. 35

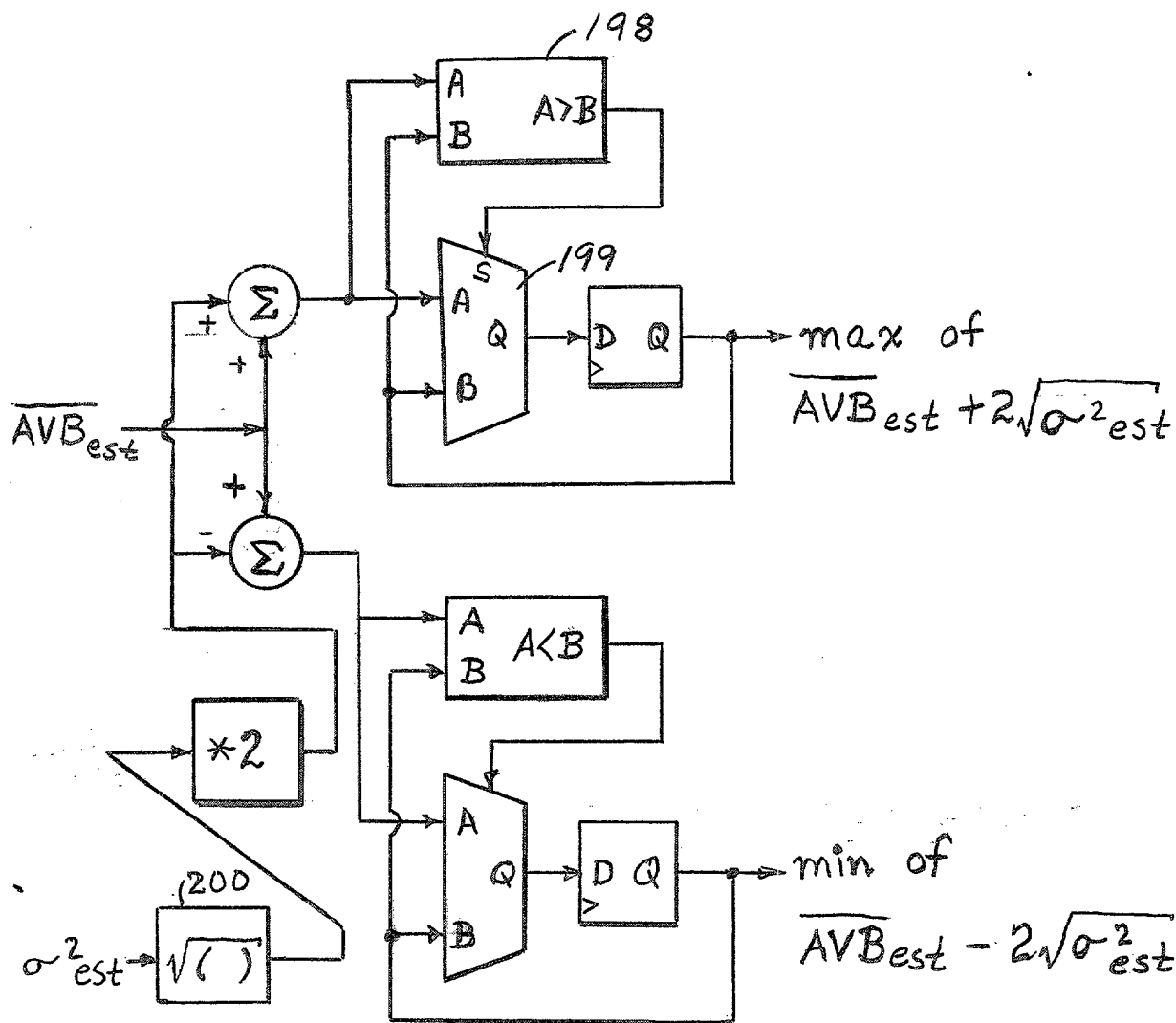


FIG. 37

VOFFSET CALCULATION

FIND THE DTS OF THE LAST
FRAME (IN DECODE ORDER)
OF THE FIRST CLIP
(DTS VL1)

FIND THE ORIGINAL DTS OF
THE FIRST FRAME TO BE
DECODED IN THE SECOND
CLIP

(DTS_{VF2})

COMPUTE

$$V_{\text{OFFSET}} = DTS_{VL1} - DTS_{VF2} + (\text{ONE VIDEO FRAME DURATION})$$

END

FIG. 38

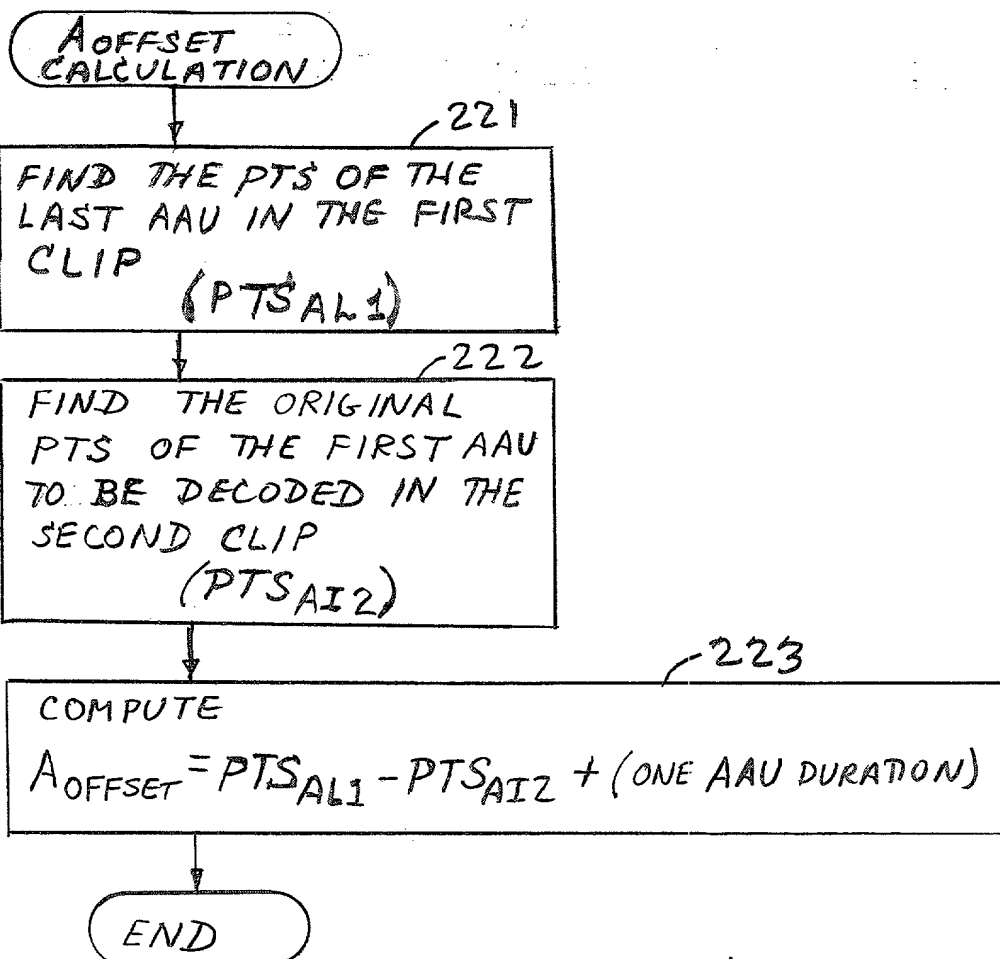


FIG. 39

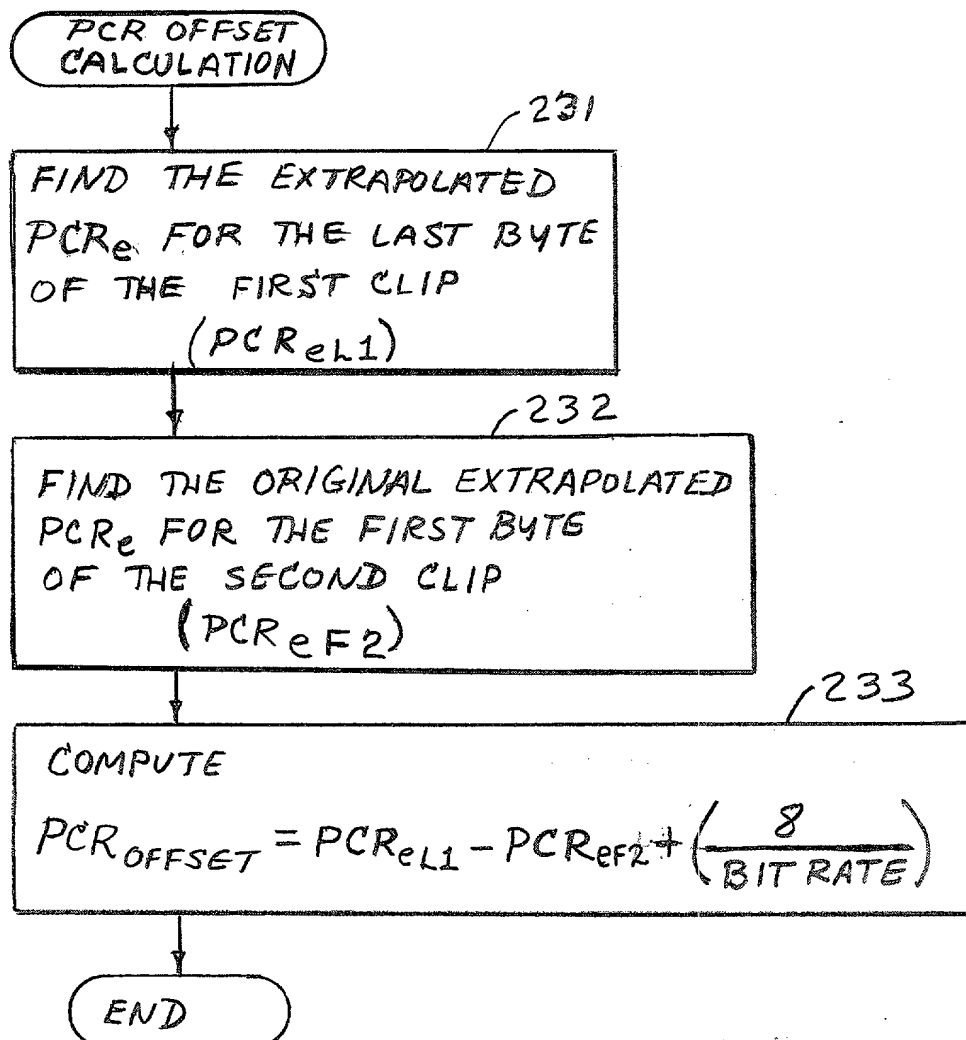


FIG. 40

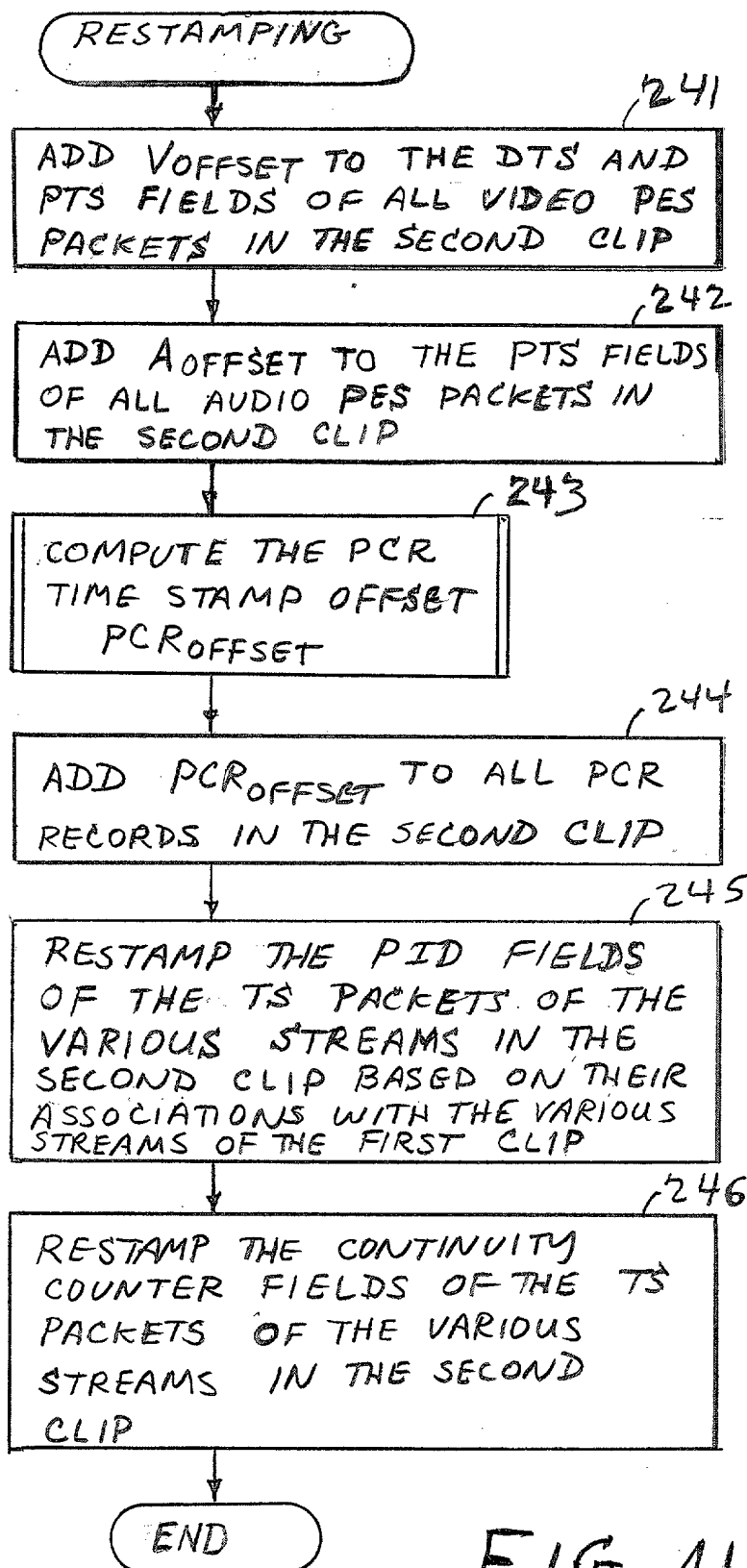


FIG. 41

RE-FORMATting

DETERMINE:

j = NO. OF NON-OBSOLETE AUDIO PACKETS IN THE FIRST TS STREAM FOLLOWING THE END OF VIDEO AT THE OUT POINT.

k = TOTAL NUMBER OF NULL PACKETS AND OBSOLETE AUDIO PACKETS IN THE SECOND TS STREAM FOLLOWING THE BEGINNING OF VIDEO AT THE IN POINT.

REPLACE ANY OF THE k NULL PACKETS OR OBSOLETE AUDIO PACKETS IN THE SECOND TS STREAM WITH CORRESPONDING ONES OF THE j NON-OBSOLETE AUDIO PACKETS IN THE FIRST TS STREAM, BEGINNING WITH THE MOST ADVANCED IN TIME PACKETS

$j > k$?

CHANGE ANY REMAINING OBSOLETE AUDIO PACKETS TO NULL TS PACKETS

FOR THE REMAINING $(j - k)$ NON-OBSOLETE AUDIO PACKETS FROM THE FIRST STREAM, CREATE $(j - k) * 188$ BYTES OF ADDITIONAL SPACE FOR THEM IN THE SPLICED TS STREAM PRIOR TO THE VIDEO FOR THE OUT POINT. (THIS ADDITIONAL SPACE MUST BE GENERATED SO AS TO MAINTAIN THE $TS = T_e + 8 / (\text{BIT RATE})$ CONDITION OF FIG. 24 FOR SEAMLESS VIDEO SPLICING.)

END

FIG. 44

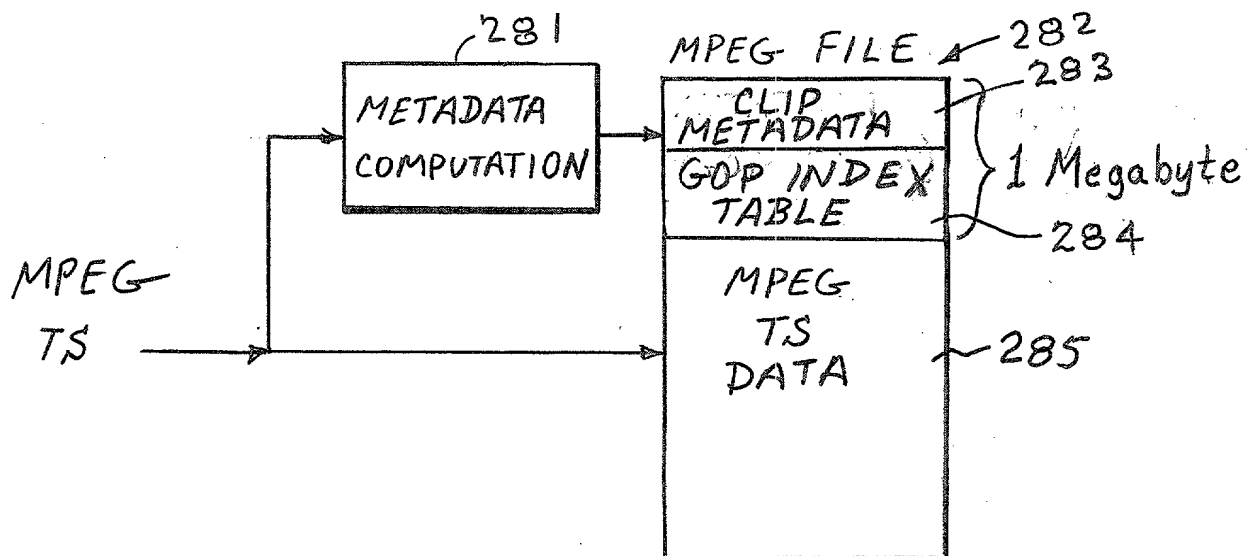


FIG. 45

284

	FRAME NO.	POINTER TO MPEG TS DATA	FLAGS	DTS, PCRe, AND OTHER GOP ATTRIBUTES
GOP 0				
GOP 1				
GOP 2				
GOP 3				
GOP 4				
GOP 5				
⋮				
⋮				
GOP n				

FIG. 46

```

graph TD
    331([GOP INDEX DECIMATION]) --> 332[GOP DECIMATION FACTOR IS INITIALLY SET TO ONE IN METADATA FOR THE CLIP]
    332 --> 333{END OF GOP INDEX REACHED DURING METADATA COMPUTATION?}
    333 -- NO --> 331
    333 -- YES --> 334[DECIMATE GOP INDEX BY A FACTOR OF 2:  
FOR i=0 TO (NMAX/2 -1),  
ENTRY(i+1) ← ENTRY(2i+2)  
NEXT i  
FOR i=NMAX/2 TO NMAX,  
INVALIDATE ENTRY(i)  
NEXT i]
    334 --> 335[INCREASE THE DECIMATION FACTOR BY A FACTOR OF 2]
    335 --> 333

```

FIG. 47

```

graph TD
    Start([METADATA CALCULATIONS  
FOR NEXT GOP]) --> D1{RESOURCES  
AVAILABLE FOR  
COMPUTING HIGH  
PRIORITY META-  
DATA? 341}
    D1 -- NO --> E1([END])
    D1 -- YES --> P1[COMPUTE HIGH PRIORITY  
METADATA FOR THE  
GOP 342]
    P1 --> D2{RESOURCES  
AVAILABLE FOR  
COMPUTING LOW  
PRIORITY META-  
DATA? 343}
    D2 -- NO --> E2([END])
    D2 -- YES --> P2[COMPUTE LOW PRIORITY  
METADATA FOR THE  
GOP 344]
    P2 --> E3([END])
  
```

FIG. 48

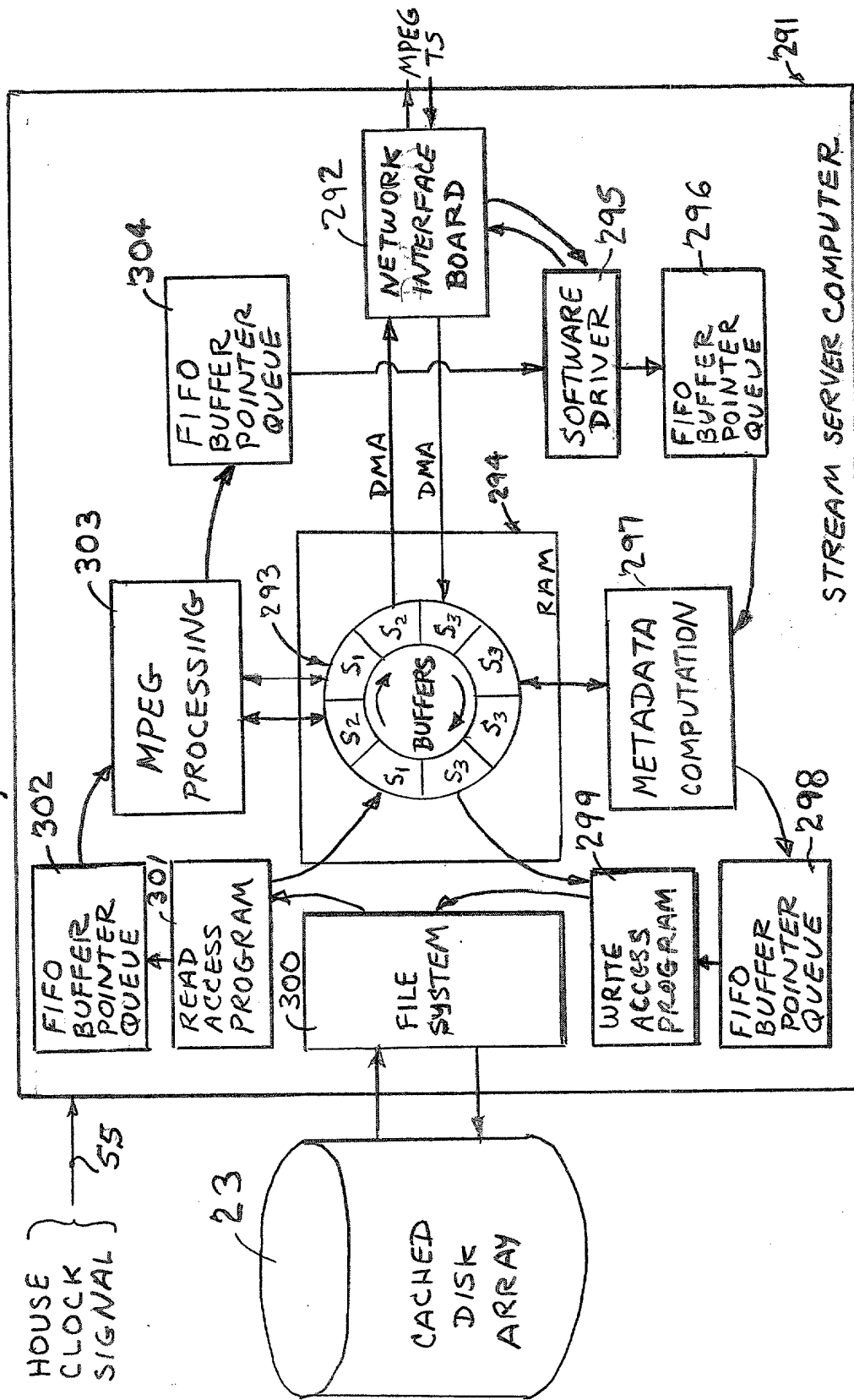


FIG. 49

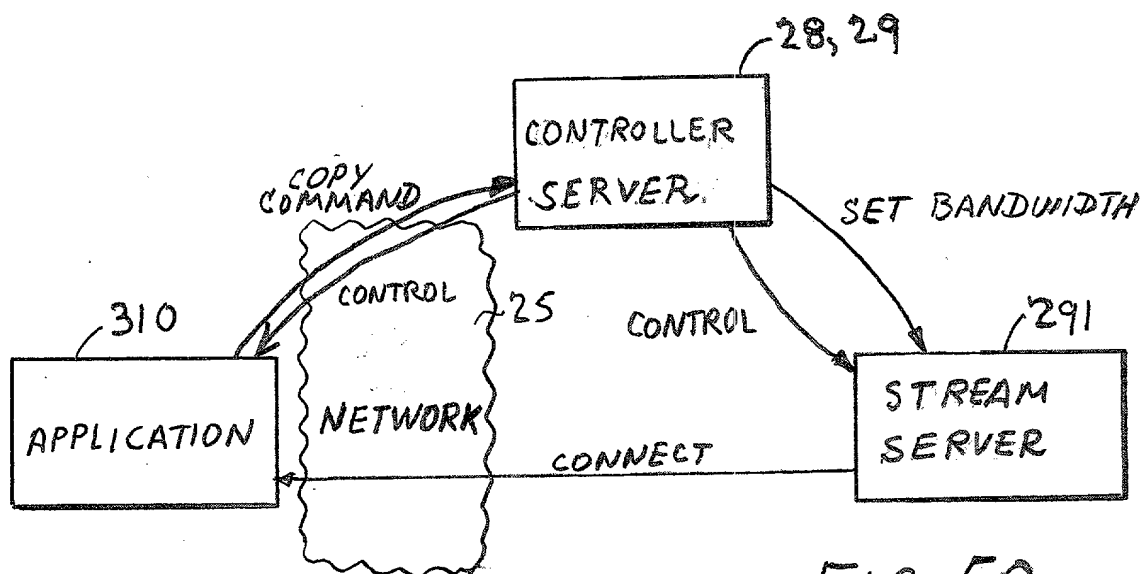


FIG. 50

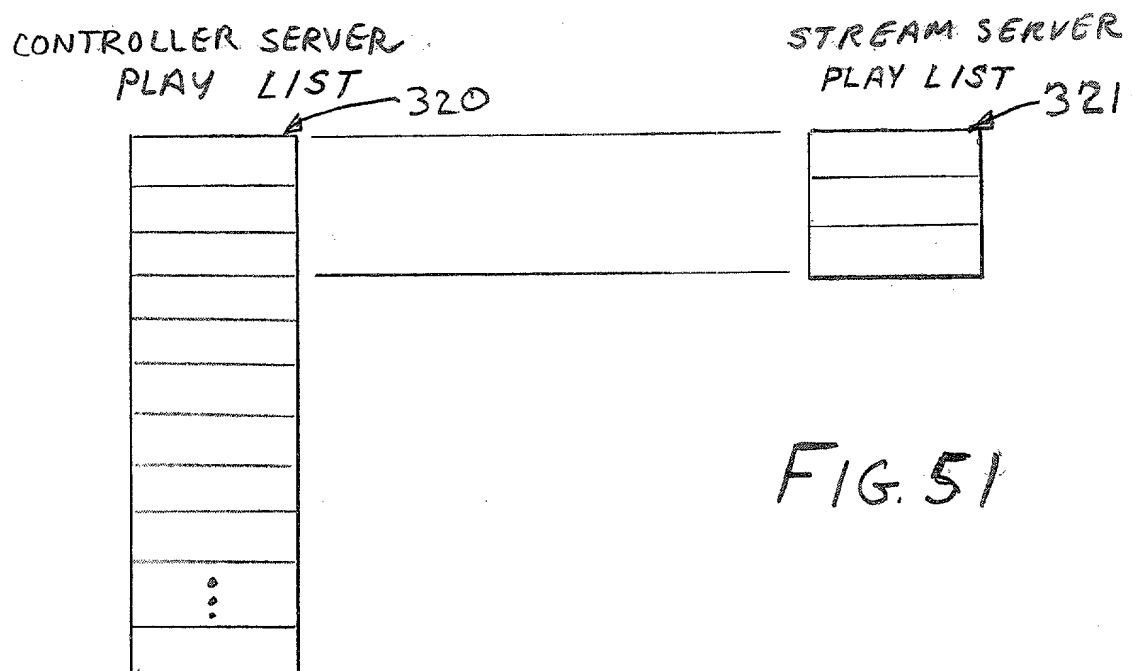


FIG. 51

PROCESSING OF TEMPORARILY CORRUPTED TRANSPORT STREAM

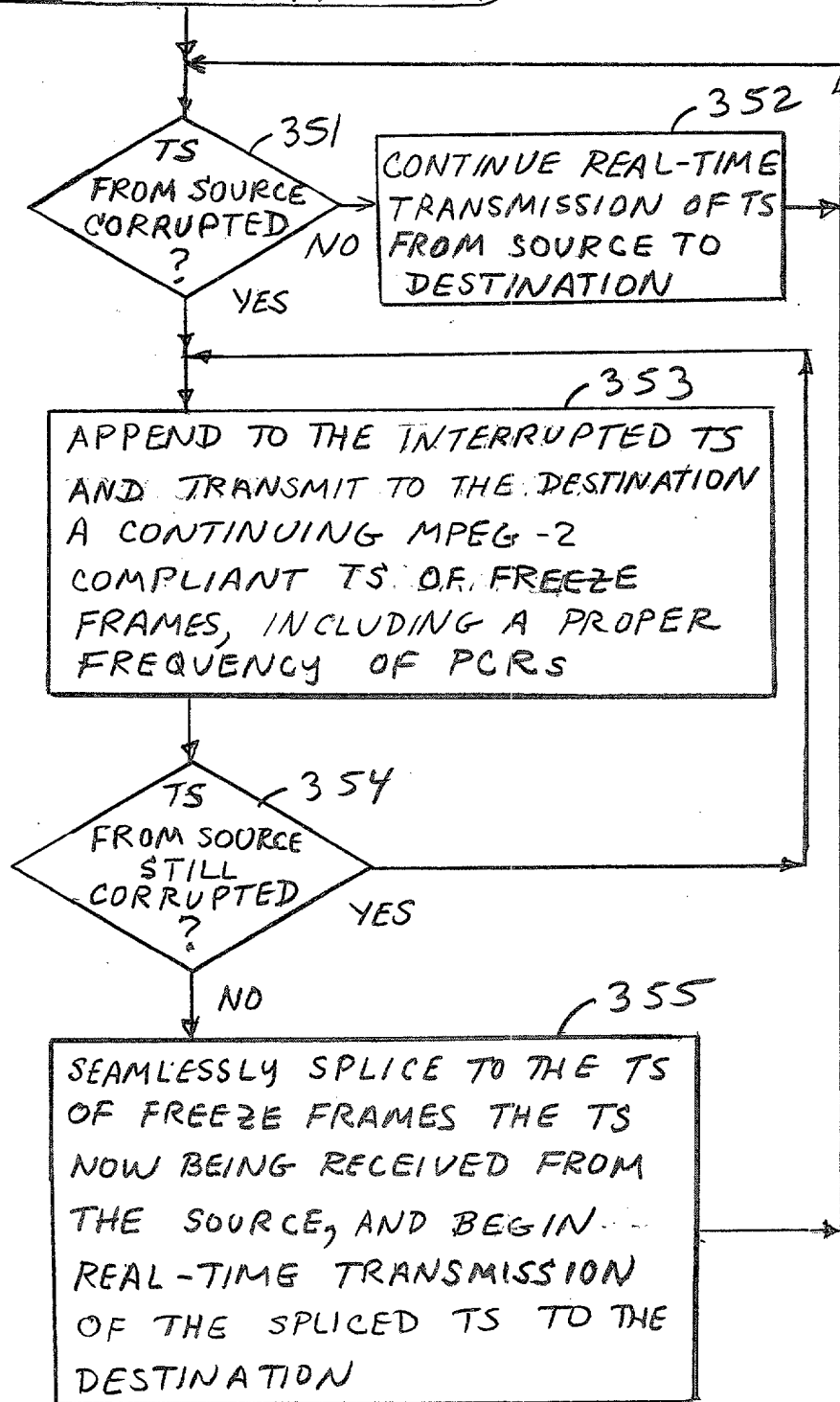


FIG. 52

DECLARATION

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or the below named inventors are the original, first and joint inventors (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled **PREPARATION OF METADATA FOR SPLICING OF ENCODED MPEG VIDEO AND AUDIO**, the Specification of which:

☒ is attached hereto.
☐ was filed on _____ as Application Serial No. _____

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims.

I acknowledge the duty to disclose to the Patent and Trademark Office all information known to me to be material to patentability of the subject matter claimed in this application, as "materiality" is defined in Title 37, Code of Federal Regulations, § 1.56.

I hereby claim priority benefits under Title 35, United States Code, § 119 of any foreign application(s) for patent, United States provisional application(s), or inventor's certificate listed below and have also identified below any foreign application for patent, United States provisional application, or inventor's certificate having a filing date before that of the application on which priority is claimed: filed

PRIORITY APPLICATION(S)			Priority Claimed
60/174,360	United States	Jan. 4, 2000	Yes
(Number)	(Country)	(Date Filed)	Yes/No
(Number)	(Country)	(Date Filed)	Yes/No

I hereby claim the benefit under Title 35, United States Code, § 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose all information known to me to be material to patentability of the subject matter claimed in this application, as "materiality" is defined in Title 37, Code of Federal Regulations, § 1.56, which


become available between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.)	(Filing Date)	(Status)
--------------------------	---------------	----------

(Application Serial No.)	(Filing Date)	(Status)
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I hereby direct that all correspondence and telephone calls be addressed to Richard C. Auchterlonie, Arnold White & Durkee, 750 Bering Drive, Houston, Texas 77057-2198, (713) 787-1400.

I HEREBY DECLARE THAT ALL STATEMENTS MADE OF MY OWN KNOWLEDGE ARE TRUE AND THAT ALL STATEMENTS MADE ON INFORMATION AND BELIEF ARE BELIEVED TO BE TRUE; AND FURTHER THAT THESE STATEMENTS WERE MADE WITH THE KNOWLEDGE THAT WILLFUL FALSE STATEMENTS AND THE LIKE SO MADE ARE PUNISHABLE BY FINE OR IMPRISONMENT, OR BOTH, UNDER SECTION 1001 OF TITLE 18 OF THE UNITED STATES CODE AND THAT SUCH WILLFUL FALSE STATEMENTS MAY JEOPARDIZE THE VALIDITY OF THE APPLICATION OR ANY PATENT ISSUED THEREON.

Inventor's Full Name:	John	Forecast
Inventor's Signature:		
Country of Citizenship:	United Kingdom	Date: 3/10/2000
Residence Address: (street, number, city, state, and/or country)	11 Charlotte Road, Newton, MA 02459	
Post Office Address: (if different from above)		

Inventor's Full Name:	Daniel	Gardere
Inventor's Signature:		
Country of Citizenship:	France	Date:
Residence Address: (street, number, city, state, and/or country)	8, rue Paul Valery, 78180, Montigny-Le-Bretonneux, France	
Post Office Address: (if different from above)		

become available between the filing date of the prior application and the national or PCT international filing date of this application:


(Application Serial No.) (Filing Date) (Status)

(Application Serial No.) (Filing Date) (Status)

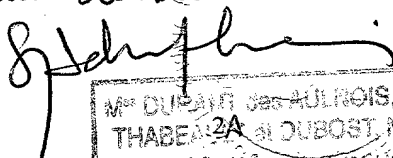
I hereby direct that all correspondence and telephone calls be addressed to Richard C. Auchterlonie, Arnold White & Durkee, 750 Bering Drive, Houston, Texas 77057-2198, (713) 787-1400.

I HEREBY DECLARE THAT ALL STATEMENTS MADE OF MY OWN KNOWLEDGE ARE TRUE AND THAT ALL STATEMENTS MADE ON INFORMATION AND BELIEF ARE BELIEVED TO BE TRUE; AND FURTHER THAT THESE STATEMENTS WERE MADE WITH THE KNOWLEDGE THAT WILLFUL FALSE STATEMENTS AND THE LIKE SO MADE ARE PUNISHABLE BY FINE OR IMPRISONMENT, OR BOTH, UNDER SECTION 1001 OF TITLE 18 OF THE UNITED STATES CODE AND THAT SUCH WILLFUL FALSE STATEMENTS MAY JEOPARDIZE THE VALIDITY OF THE APPLICATION OR ANY PATENT ISSUED THEREON.

Inventor's Full Name:	John	Forecast
Inventor's Signature:		
Country of Citizenship:	United Kingdom	Date:
Residence Address: (street, number, city, state, and/or country)	11 Charlotte Road, Newton, MA 02459	
Post Office Address: (if different from above)		

Inventor's Full Name:	Daniel	Gardere
Inventor's Signature:		
Country of Citizenship:	France	Date: 26 Mars 2000
Residence Address: (street, number, city, state, and/or country)	8, rue Paul Valery, 78180, Montigny-Le-Bretonneux, France	
Post Office Address: (if different from above)		

Vu pour la certification matérielle
de la signature de Daniel Gardere
apposée ci-dessus



M^e DUPAIN Jean-AUGUSTE, PISANI
THABEAUD et DOUBOST, Notaires
10, rue de la République
75008 PARIS

